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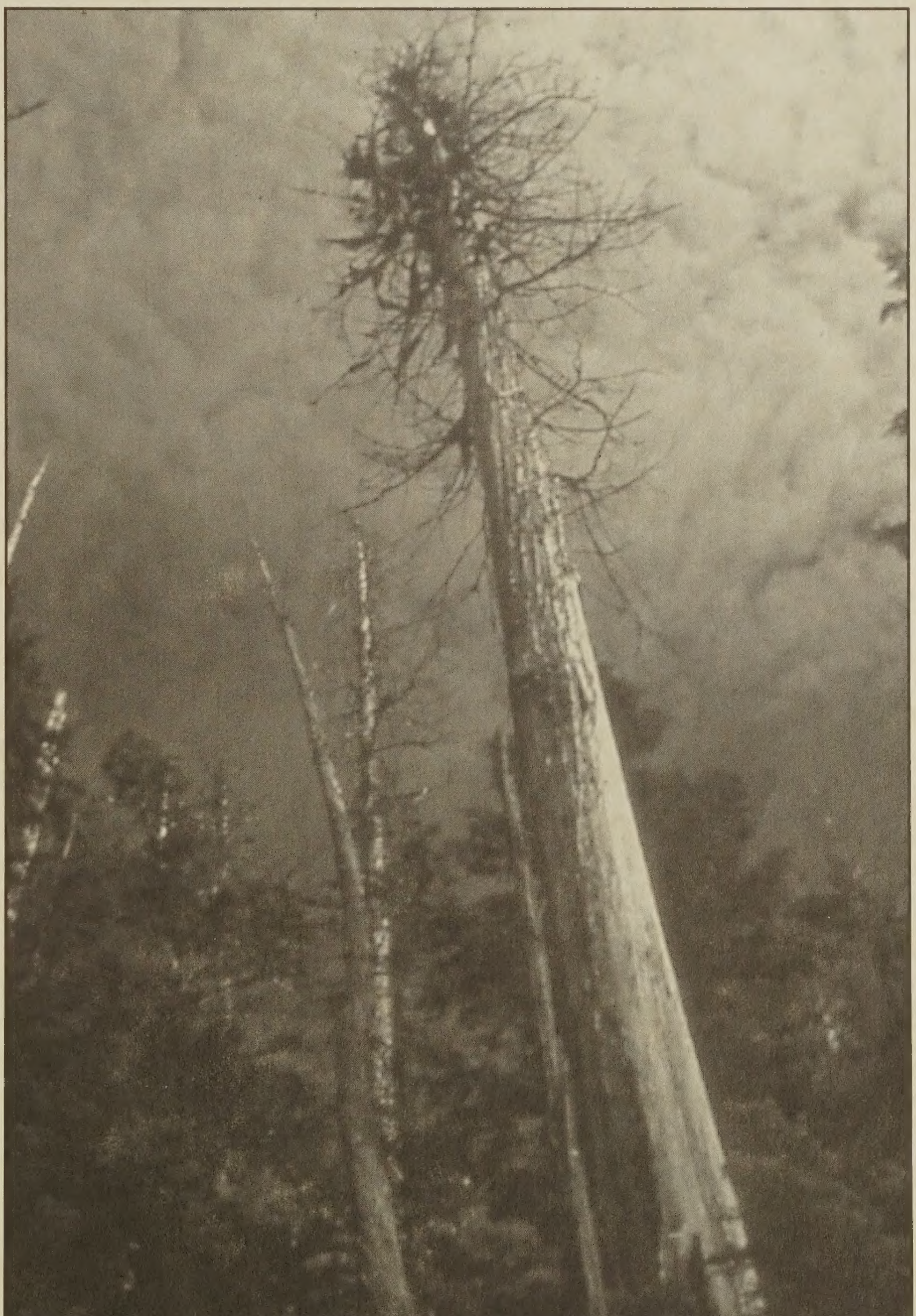
Forest Health Protection Report

Forest Insect and Disease Conditions in Alaska - 2000



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FOREST INSECT AND DISEASE CONDITIONS IN ALASKA - 2000

General Technical Report R10-TP-86

January, 2001

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Table of Contents

CONDITIONS IN BRIEF 1
THE ROLE OF DISTURBANCE IN ECOSYSTEM MANAGEMENT 5

STATUS OF INSECTS........ 9
INSECTS AS AGENTS OF DISTURBANCE 9

BARK BEETLES 10
Spruce Beetle 10
Engravers 14
Miscellaneous Bark Beetles 15

DEFOLIATORS 18
SOUTHEAST ALASKA DEFOLIATOR PLOTS 18
Spruce Needle Aphid 18
Western Black-Headed Budworm 18
Hemlock Sawfly 18
Spruce Budworm and Coneworm 19
Larch Sawfly 19
Aspen Leaf Miner 19
Birch Defoliation 20
Large Aspen Tortrix 20
Cottonwood Defoliation 20
Willow Leaf Blotchminer 22
Gypsy Moth 22
Alder Woolly Sawfly 22
Spider Mites: Acarina 22

INVASIVE PESTS 23
Sitka Spruce Weevil 23
European Black Slug: Limacidae 23
Bird Vetch 23

STATUS OF DISEASES 28
ECOLOGICAL ROLES OF FOREST DISEASES 28

STEM DISEASES 31
Hemlock Dwarf Mistletoe 31
Hemlock Canker 32
Spruce Broom Rust 32
Western Gall Rust 32

HEART ROTS OF CONIFERS 32

STEM DECAY OF HARDWOODS 34

SHOOT BLIGHTS and CANKERS 34
Sirococcus Shoot Blight 34
Shoot Blight of Yellow-cedar 35
Canker Fungi 35

FOLIAR DISEASES 35

Spruce Needle Rust 35
Spruce Needle Blights 36
Hemlock Needle Rust 36
Willow Rust 36
Foliage Diseases of Cedars 36

ROOT DISEASES **37**
Armillaria Root Disease 37
Tomentosus Root Disease 37
Annosus Root & Butt Rot 38

DECLINES AND ABIOTIC FACTORS ***39***
Yellow-cedar Decline 39
Avalanche Damage 42
Water Damage 42
Hemlock Fluting 42

STATUS OF ANIMAL DAMAGE ***43***
Moose 43
Snowshoe Hare 43
Porcupine 43
Bear 43

APPENDICES ***45***
INTEGRATED PEST MANAGEMENT 46
SUBMITTING INSECTS AND DISEASES FOR IDENTIFICATION 48
BIOLOGICAL EVALUATIONS, TECHNICAL REPORTS, AND PUBLICATIONS 49
ALASKA ECOREGION DESCRIPTIONS 50
WORLD WIDE WEB LINKS 57
INFORMATION AVAILABLE FROM STATEWIDE AERIAL SURVEYS 59

LIST OF TABLES

Table 1. 2000 forest insect and disease activity in Alaska by land ownership. 3
Table 2. Acreage having active insect damage, by year since 1995, and the cumulative area. 4
Table 3. Frequency of agent in the respective ecoregions. 8
Table 4. Engraver activity 15
Table 5. Suspected effects of common diseases on ecology in Alaskan forests.. 29
Table 6. Common wood decay organisms of live trees in Alaska 33
Table 7. Acreage affected by yellow-cedar decline in southeast Alaska in 2000 41

LIST OF MAPS

Map 1. Ecosystem Sections Map 7
Map 2. A Decade of Spruce Beetles: Year 2000 16
Map 3. Kenai Sequential, 1995-2000, Spruce Beetle Map 17
Map 4. Spruce Aphid and Willow Leaf Blotchminer Defoliation Map 21
Map 5. General Forest Pest Activity in 2000. 25
Map 6. 1999 Survey Flight Paths Showing Ownership 26
Map 7. Cedar Decline in Southeast Alaska. 40
Map 8. USGS Quadrangle Locator Map 61

FOREST INSECT AND DISEASE CONDITIONS IN ALASKA -- 2000

CONDITIONS IN BRIEF

Aerial detection mapping is conducted annually to document the location and extent of active forest insect and disease damage. These surveys generally cover approximately 1/3 of the forested land in Alaska. Smoke from large wildfires in interior Alaska and inclement weather precluded flights into many areas of concern. Even so, over 27 million acres throughout Alaska were surveyed. This is the second year of overall decreased insect activity; although, areas not often affected by insect damage such as Sleetmute or Elim, did have insect damage reported. The most important diseases and declines in Alaska are characterized as chronic conditions and remain relatively unchanged.

INSECTS:

Total area of active **Spruce Beetle** infestation decreased in 2000 to only 86,038 acres, continuing the decline in mapped acreage, which began in 1997. In areas which have recently been heavily impacted, such as Iliamna Lake, the Copper River Valley, the west side of Cook Inlet, the Anchorage Bowl, the northern Kenai Peninsula and the eastern portion of Kachemak Bay, population levels have declined dramatically due to lack of host material (i.e., the beetles have run out of live spruce trees to attack). Some active areas persist, where suitable host material remains or where new areas of disturbance present the spruce beetle with fresh opportunities for population increases. Heavy activity continues near Lake Clark along the Tlikakila River and in the Hanagita River Valley in the Wrangell-St. Elias National Park and Preserve. Spruce Beetle activity was identified in two new areas. One active area was around the community of Sleetmute and the other near Elim on Norton Sound.

Spruce beetle activity in southeast Alaska was at a low of 2700 acres from a high of 35,700 acres in 1996 and 6,556 acres in 1999. Much of this activity was in the Chilkat and Chilkoot drainages near the Canadian border. There were only 200 acres of activity in Glacier Bay National Park east of Gustavus and 100 acres on the outer islands west of Prince of Wales Island. No new acres were infested along the Taku River near the Canadian border.

Spruce needle aphid defoliation occurred on approximately 36,000 acres in southeast Alaska from Cape Decision, at the southern tip of Kuiu Island, to Yakutat Bay. Most of the defoliation was located in the Juneau area and a few miles to the northwest of Juneau in Glacier Bay National Park. A smaller amount of defoliation was distributed along the western half of Baranof and Chichagof Islands. Sitka spruce were affected along the beach fringe and higher on mountain slopes.

Spruce budworm activity, along the Yukon River, appears to have collapsed. Although, an area of white spruce, approximately 41,000 acres, north of Fort Yukon on the Christian River was lightly defoliated. The cause is not known but could be spruce budworm or spruce bud moth.

Willow leaf blotchminer defoliation continued for the third consecutive year; nearly 35,000 acres of defoliated willow were aerially detected in 2000. In the last two years, most of the willow defoliation was located in the upper Yukon and Porcupine River valleys; this year, blotchminer defoliation was found as far west and south as McGrath. Mortality of willow is occurring in interior Alaska.

Large Aspen Tortrix defoliation continued its decline in 2000, with 5,576 acres mapped. **Aspen Leaf Miner** was also prevalent throughout interior Alaska.

Larch sawfly continues to be active throughout the range of larch in interior Alaska. Defoliation, however, was significantly reduced over 1999 levels. Approximately 65,000 acres of defoliated larch were detected this year vs. more than 190,000 acres of defoliated larch in 1999. In many of the previously defoliated areas, patches of larch mortality are beginning to appear; either due to the direct effects of the sawfly or by the larch beetle attacking stressed, defoliated trees. The major area of sawfly activity continues to be from the Alaska Range west to the Kuskokwim River. Larch sawfly was once again reported in the Mat-Su Valley and Anchorage Bowl areas defoliating ornamental larch. This was no doubt an accidental introduction.

Hemlock sawfly defoliated approximately 5,200 acres in southeast Alaska concentrated in Kasaan Bay, Prince of Wales Island, Burroughs Bay north of Ketchikan, and Windham Bay east of Admiralty Island.

DISEASES:

The most important diseases and declines of Alaskan forests in 2000 were wood decay of live trees, root disease of white spruce, hemlock dwarf mistletoe, and yellow-cedar decline. Except for yellow-cedar decline, trees affected by these diseases are difficult to detect by aerial surveys. Nonetheless, all are chronic factors that significantly influence the commercial value of the timber resource and alter key ecological processes including forest structure, composition, and succession. Wildlife habitat is enhanced through the development of hollow tree cavities by heart rot fungi, and witches' brooms by hemlock dwarf mistletoe and broom rust fungi.

In southeast Alaska, approximately one-third of the gross volume of forests is defective due to **stem** and **butt rot fungi**. **Hemlock dwarf mistletoe** continues to cause growth loss, top-kill, and mortality in old-growth forests; its impact in managed stands depends on the abundance of large infected trees remaining on site after harvesting.

Approximately 500,000 acres of **yellow-cedar decline** have been mapped across an extensive portion of southeast Alaska. Snags of yellow-cedar accumulate on affected sites and forest composition is substantially altered as yellow-cedar trees die, giving way to other tree species. The wood in dead standing trees remains valuable long after tree death and salvage opportunities for this valuable resource are now being recognized.

In south-central and interior Alaska, **tomentosus root rot** continues to cause growth loss and mortality of white spruce in all age classes. Stem, butt, and root rot fungi cause considerable defect in white spruce, paper birch and aspen stands. Saprophytic decay of spruce bark beetle-killed trees, primarily caused by the **red belt fungus**, continues to rapidly develop on and degrade dead spruce trees.

Spruce needle rust occurred at high levels in several areas of southeast Alaska for the second consecutive year. Cone and other foliar diseases of conifers were generally at low levels throughout Alaska in 2000. Canker fungi were at endemic levels, causing substantial, but unmeasured, damage to hardwood species in south-central and interior Alaska.

Other:

Three specific introduced pests are causing concern in the Anchorage area. The **Sitka spruce weevil** and the **European black slug** may become established in Alaska if detection and eradication methods are not employed early. **Bird vetch**, *Vicca cracca*, has been observed as an aggressive plant invader along portions of the Seward highway in South Anchorage. It has been spotted along trails in Chugach State Park and on sites in the Hillside neighborhoods.

In localized areas of southeast Alaska, feeding by **porcupines** and **brown bears** continues to cause tree damage to several conifer species.

Table 1. 2000 forest insect and disease activity as detected during aerial surveys in Alaska by land ownership[1] and agent[2]. All values are in acres.

Damage Agent	State & Private	National Forest	Other Federal	Native Corp.	Total 2000	*Change From 1999*
Alder Defoliation[3]	147	5,161	261	0	5,570	3,755
Aspen Defoliation[3]	3,788	0	2,076	1,103	6,967	6,967
Birch Defoliation[3]	461	0	2,160	4	2,625	-128
Blowdown/Windthrow	55	267	0	0	322	-75
Cottonwood Defoliation[4]	205	5,185	0	0	5,389	-201
Engraver Beetle[5]	4,715	0	17,565	667	22,947	19,169
Hemlock Sawfly	264	4,552	0	292	5,108	5,019
Landslide / Avalanche	286	615	27	30	957	882
Larch Sawfly	3,839	0	41,993	19,028	64,859	-94,401
Large Aspen Tortrix	1,991	0	2,107	1,479	5,576	-7,760
Porcupine Damage	0	398	10	0	407	62
Spruce Aphid	9,124	22,390	5,325	733	37,572	33,319
Spruce Beetle	32,011	1,867	32,958	19,202	86,038	-167,227
Spruce Budworm	0	0	12,556	28,511	41,066	40,358
Water Damage	317	67	55	13	452	-2,120
Willow Defoliation[3]	6,489	0	16,171	13,343	36,002	-144,394
Total Acres	**63,692**	**40,502**	**133,264**	**84,405**	**321,857**	**-306,775**

[1]ownership derived from 1999 version of Land Status GIS coverage, state of AK, DNR/Land records Information Section

[2] Table entries do not include many of the most destructive diseases (e.g., wood decays and dwarf mistletoe) because these losses are not detectable in aerial surveys. Cedar decline acres can be seen in table 7.

[3]significant contributors include leaf miners and leaf rollers for the respective host

[4]significant contributors include cottonwood leaf beetle and leaf rollers

[5]includes acres where both engraver beetle and spruce beetle infested the same area

Table 2. Acreage having active insect damage, by year, since 1995, and the cumulative area (in thousands of acres) affected for the last 6 years.

Damage Agent	1995 Total	1996 Total	1997 Total	1998 Total	1999 Total	2000 Total	Cumulative Totals[1]
Spruce beetle	893.9	1,133.0	563.7	316.8	253.3	86.0	**2046.3**
Larch sawfly	116.9	606.9	267.6	461.8	159.3	64.9	**1544.6**
Spruce budworm	279.3	235.9	38.4	87.8	0.7	41.1	**501.0**
Willow defoliation	5.6	50.1	3.5	123.1	180.4	36.0	**338.5**
Birch defoliation[2]	0.9	3.2	271.9	0.5	2.8	2.6	**280.4**
Spruce aphid	0.1	0.5	0.5	46.4	4.3	37.6	**88.6**
Large aspen tortrix	32.4	6.4	5.1	21.8	13.3	5.6	**81.9**
Engravers[3]	6.7	14.2	8.9	14.3	3.9	23.0	**70.1**
Black-headed budworm	13.0	1.2	30.8	--	--	--	**44.9**
Cottonwood defoliation[4]	3.5	5.4	3.0	6.6	5.6	5.4	**29.3**
Hemlock sawfly	1.1	8.3	6.6	3.9	--	5.1	**25.2**
Total thousands acres	**1353.4**	**2065.1**	**1200.0**	**1083.0**	**623.6**	**307.3**	**5050.8**

[1] The same stand can have active infestation for several years. The cumulative total is a union of all areas for 1995 through 2000.

[2] Tallies represent polygons coded to BID (birch defoliation), BAP (birch aphid) and BLR (birch leaf roller).

[3] Tallies represent polygons coded to ipb (*Ips* and spruce beetle combination) and polygons coded only to IPS.

[4] Tallies represent polygons coded to CWD (cottonwood defoliation), CLB (cottonwood leaf beetle) and CLM (cottonwood leaf miner).

THE ROLE OF DISTURBANCE IN ECOSYSTEM MANAGEMENT

To the casual observer, forests may appear to be unchanging. In fact, most forests are in some stage of re-establishment after one or more disturbances. In Alaska, geological processes, climatic forces, insects, plant diseases, and the activities of animals and humans have shaped forests. To practice ecosystem management, we must understand how these cycles of disturbances have shaped and continue to influence various forest ecosystems.

Disturbances result in changes to ecosystem function. In forests, this often means the death or removal of trees. Disturbances caused by physical forces such as volcanoes, earthquakes, storms, droughts, and fire can affect the entire plant community, although some species may be more resistant to damage than others. Insects, plant diseases, animal and human activities are usually more selective, directly affecting one or several species.

Figure 1. Fire is a frequent and dramatic form of disturbance in interior Alaska.

Cycles of disturbance and recovery repeat over time and across landscapes. From evidence of past disturbances on a landscape, we can predict what type of disturbance is likely to occur in the future. Landscapes supporting large areas of single age stands indicate rare, but intense large-scale disturbances. Landscapes with a variety of age classes and species suggest more frequent smaller scale events. Usually, several types of disturbances at various scales of space, time, and intensity have influenced forest structure and composition on a given site. The role of disturbance in ecological processes is well illustrated in Alaska's two distinct forest ecosystem types and transition zones.

The temperate rain forests of southeast Alaska are dominated by western hemlock and Sitka spruce. Alaskan yellow-cedar, western red cedar, shore pine and mountain hemlock are also important components. Trees on productive sites can attain great size due to abundant rainfall and moderate temperatures. Wind is the major disturbance agent in southeast. Degree of impact and scale depends on stand composition, structure, age and vigor and as well as wind speed, direction, duration and topographic effects on wind flow. The forest type most susceptible to wind throw is mature spruce-hemlock on productive, wind-exposed sites. The large, top-heavy canopies act as sails and uprooting is common, resulting in soil churning, which expedites nutrient cycling and increases soil permeability. Even-aged forests develop following large-scale catastrophic wind events. Old-growth forest structure develops in landscapes protected from prevailing winds. In these areas, small gap-forming events dominate. Trees are long-lived, but become heavily infected with heart-rot fungi, hemlock dwarf mistletoe, and root rot fungi as they age. Weakened trees commonly break under the stress of gravity and snow loading. Canopy gaps generated this way do not often result in exposed mineral soil.

The boreal forests of interior Alaska are comprised of white spruce, black spruce, birch, aspen and poplar. The climate is characterized by long, cold winters, short, hot summers, and low precipitation. Cold soils and permafrost limit nutrient cycling and root growth. Topographic features strongly influence microsite conditions; north-facing slopes have wet, cold soils, whereas south-facing slopes are warm and well drained during the growing season. Soils are usually free from permafrost along river drainages, where flooding is common. Areas more distant from rivers are usually underlain by permafrost and are poorly drained. Fire is the major large-scale disturbance agent; lightening strikes are very common. All tree species are susceptible to damage by fire, and all are adapted, to various degrees, to regeneration following fire. Fire impacts go beyond removal of vegetation; depending on the intensity and duration of a fire, soil may be warmed, upper layers of permafrost may thaw, and nutrient cycling may accelerate. Patterns of forest type development across the landscape are defined by the basic silvics of the species involved. Hardwoods are seral pioneers, re-sprouting from roots or stumps.

White spruce stands are usually found on better-drained soils, along flood plains, river terraces, and on slopes with southern exposure. Black spruce and tamarack occur in areas of poor drainage, on north-facing slopes, or on upland slopes more distant from rivers where permafrost is common.

South-central Alaska is a transition zone between the coastal marine climate of southeast and the continental climate of the interior. These forest communities are more similar to those in the interior, except where Sitka spruce and white spruce ranges overlap and the Lutz spruce hybrid is common. Fire has been a factor in the forest landscape patterns we see today. These fires, however, were mostly the result of human activity; lightning strikes are uncommon in the Cook Inlet area. Major disturbances affecting these forests in the past century have been human activity and spruce beetle caused mortality. Earthquakes, volcanic eruptions, and flooding following storm events have also left significant signatures on the landscape.

Disturbances play an important role in shaping forest composition, structure, and development. With knowledge of disturbance regimes, managers can understand key processes driving forest dynamics and gain insight into the resiliency (the ability to recover) and resistance (the ability to withstand change) of forests to future disturbance. As we improve our understanding of the complexities of these relationships, we are better able to anticipate and respond to natural disturbances and mimic the desirable effects with management activities. Ecological classification is one tool available to help us understand disturbance patterns.

Several useful systems of classification have been developed for Alaska's ecosystems and vegetation. Efforts to refine and standardize these classifications across all ownerships produced a unified map in 2000. Field and resource specialists representing a variety of organizations, including representatives from Canada, came together to evaluate two existing maps (Gallant et al. 1995 and Nowacki and Brock 1995) along with additional resource information. Line placement was refined using the best available data. Delineation criteria ultimately included climate, phsyiography, vegetation, and glaciation.

In Alaska, three distinct climatic-vegetation regimes exist representing polar, boreal, and maritime. These regimes cover broad areas and grade from one to another across the state. To accommodate this spatial arrangement, ecoregion groups were arranged in a triangular manner reflecting the major regimes and gradations between them (Figure 2). Through this projection (a tri-archy), the natural associations among ecoregion groups are displayed as they occur on the land without loss of information (i.e., retains the spatial interrelations of the groups).

Throughout this report, we make reference to the Ecoregions of Alaska (see map on following page). Brief Ecoregion descriptions are included in Appendix D.

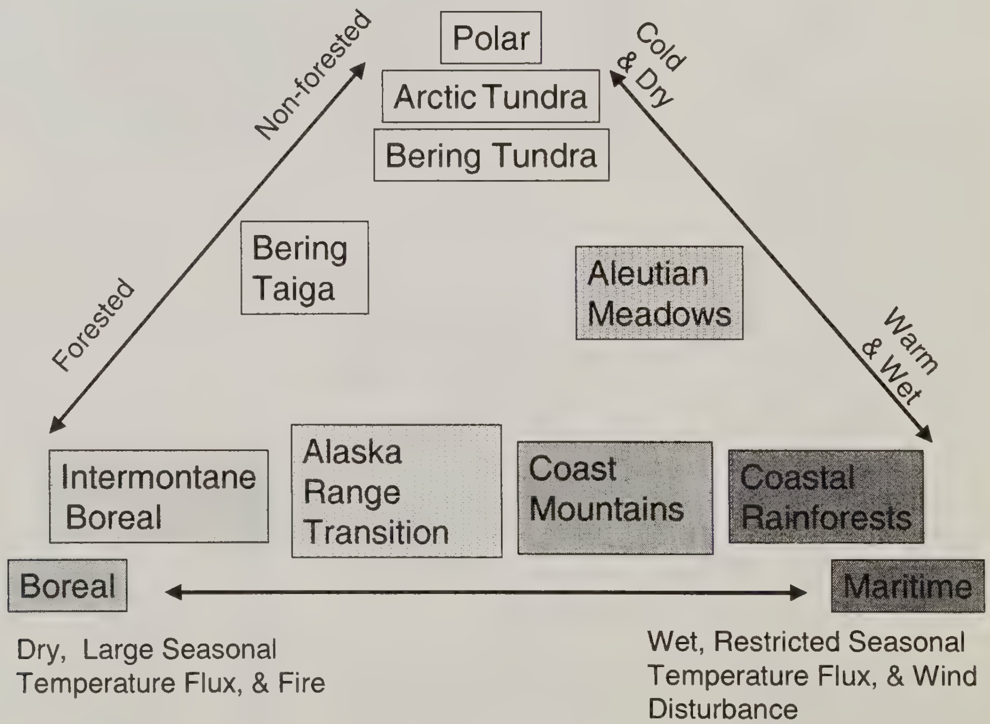


Figure 2. This tri-archy illustrates the major regimes and gradations between the Alaska ecoregions.

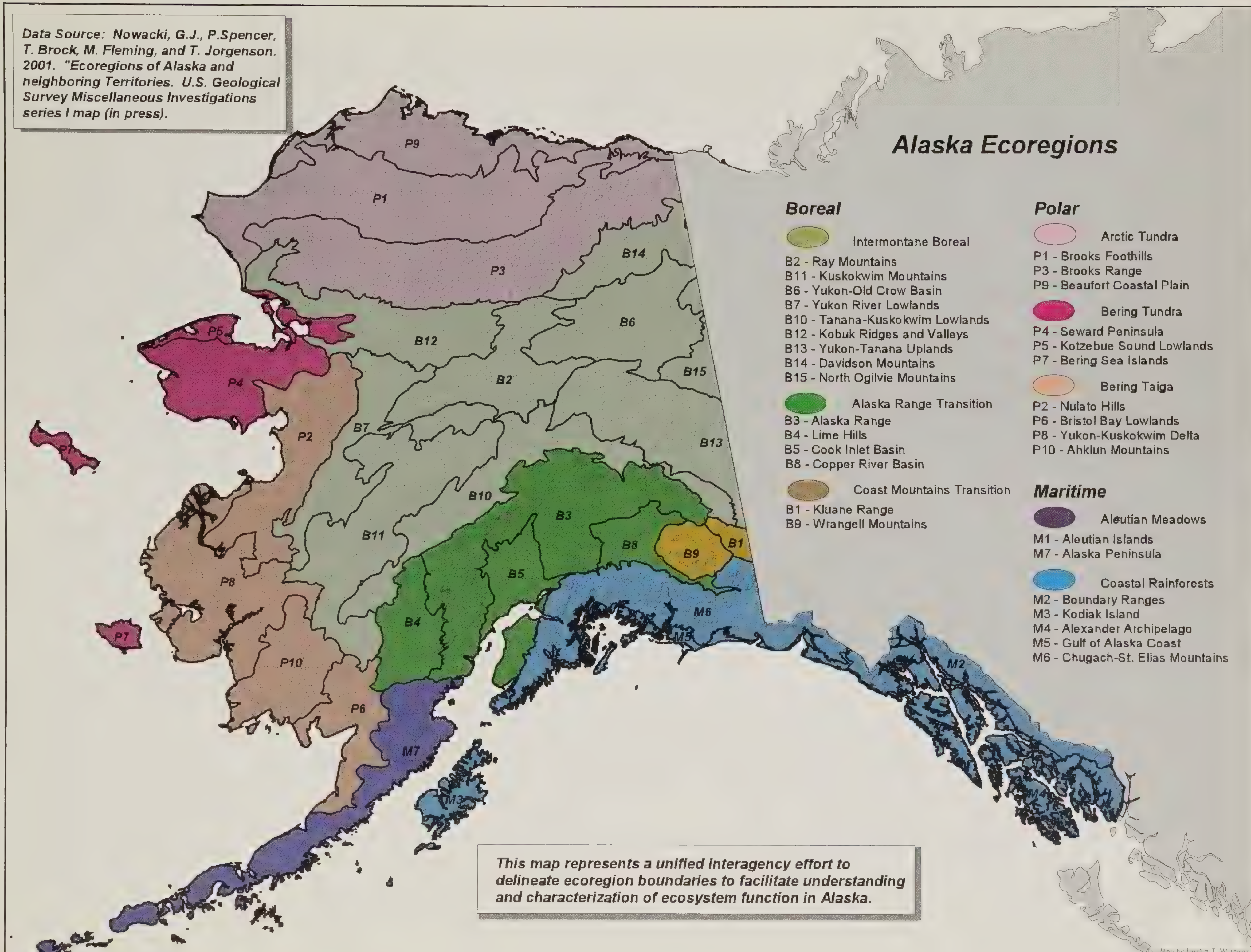

Data Source: Nowacki, G.J., P.Spencer, T. Brock, M. Fleming, and T. Jorgenson. 2001. "Ecoregions of Alaska and neighboring Territories. U.S. Geological Survey Miscellaneous Investigations series I map (in press).
Alaska Ecoregions
Boreal
Intermontane Boreal
B2 - Ray Mountains
B11 - Kuskokwim Mountains
B6 - Yukon-Old Crow Basin
B7 - Yukon River Lowlands
B10 - Tanana-Kuskokwim Lowlands
B12 - Kobuk Ridges and Valleys
B13 - Yukon-Tanana Uplands
B14 - Davidson Mountains
B15 - North Ogilvie Mountains
Alaska Range Transition
B3 - Alaska Range
B4 - Lime Hills
B5 - Cook Inlet Basin
B8 - Copper River Basin
Coast Mountains Transition
B1 - Kluane Range
B9 - Wrangell Mountains
Polar
Arctic Tundra
P1 - Brooks Foothills
P3 - Brooks Range
P9 - Beaufort Coastal Plain
Bering Tundra
P4 - Seward Peninsula
P5 - Kotzebue Sound Lowlands
P7 - Bering Sea Islands
Bering Taiga
P2 - Nulato Hills
P6 - Bristol Bay Lowlands
P8 - Yukon-Kuskokwim Delta
P10 - Ahklun Mountains
Maritime
Aleutian Meadows
M1 - Aleutian Islands
M7 - Alaska Peninsula
Coastal Rainforests
M2 - Boundary Ranges
M3 - Kodiak Island
M4 - Alexander Archipelago
M5 - Gulf of Alaska Coast
M6 - Chugach-St. Elias Mountains
P9
P1
P3
P5
P4
P7
P2
P8
P10
P6
B12
B14
B6
B2
B15
B7
B13
B10
B11
B3
B8
B9
B1
B5
B4
M6
M7
M2
This map represents a unified interagency effort to delineate ecoregion boundaries to facilitate understanding and characterization of ecosystem function in Alaska.

Table 3. Frequency (number of years between 1989-2000) an agent has been mapped in each ecoregions.

	Alder Defoliators	Aspen Defoliators	Birch Defoliators	Cottonwood Defoliators	Willow Defoliators	Hemlock Defoliators	Larch Defoliators	Spruce Defoliators	Spruce Needle Aphid	Bark Beetles	Cedar Decline	Porcupine Damage	Spruce Rust	Windthrow
POLAR														
Arctic Tundra														
Brooks Range	1	-	-	-	-	-	-	-	-	4	-	-	2	-
Bering Tundra														
Seward Peninsula	-	-	-	-	2	-	-	-	-	3	-	-	-	-
Bering Taiga														
Ahklun Mts.	-	-	-	-	1	-	-	-	-	3	-	-	-	-
Nulato Hills	-	-	-	2	2	-	-	-	-	8	-	-	1	-
Yukon-Kuskokwim Delta	-	-	1	-	1	-	-	-	-	6	-	-	-	-
Bristol Bay Lowlands	-	-	-	-	1	-	-	-	-	1	-	-	1	-
BOREAL														
Intermontane														
Kobuck Ridges and Valleys	-	5	1	3	5	-	1	-	-	3	-	-	2	-
Ray Mountains	-	9	5	2	10	-	5	7	-	10	-	-	2	-
Davidson Mts.	-	1	1	1	4	-	-	-	-	5	-	-	-	-
Yukon-Old Crow Basin	-	4	3	2	11	-	1	2	-	11	-	-	3	-
North Ogilvie Mts.	-	2	1	-	7	-	-	-	-	2	-	-	1	-
Yukon-Tanana Uplands	-	8	4	2	7	-	5	8	-	11	-	-	1	-
Tanana-Kuskokwim Lowlands	-	9	8	6	10	-	10	7	-	12	-	-	4	-
Yukon River Lowlands	-	4	3	5	11	-	5	9	-	12	-	-	3	-
Kuskokwim Mts.	-	2	1	1	3	-	5	1	-	12	-	-	1	-
Alaska Range Transition														
Lime Hills	-	1	2	1	1	-	2	1	-	7	-	-	-	-
Alaska Range	-	8	1	5	6	-	1	2	-	12	-	-	1	-
Cook Inlet Basin	-	12	8	9	6	1	-	1	-	12	-	-	3	-
Copper River Basin	-	4	1	1	2	-	-	-	-	11	-	-	4	-
Coast Mountains Transition														
Wrangell Mountains	-	1	-	-	-	-	-	-	-	8	-	-	-	-
Kluane Range	-	1	-	-	-	-	-	-	-	2	-	-	-	-
MARITIME														
Aleutian Meadows														
Alaska Peninsula	-	-	-	-	-	-	-	2	-	10	-	-	-	-
Coastal Rainforests														
Alexander Archipelago	3	-	-	6	-	12	-	1	10	12	3	9	1	9
Boundary Ranges	7	-	-	9	-	9	-	5	2	12	1	5	-	4
Chugach-St. Elias Mts.	1	8	5	5	3	5	-	6	3	11	1	1	2	3
Gulf of Alaska Coast	-	1	1	10	4	8	-	7	3	12	2	2	2	5
Kodiak Island	-	-	-	-	-	-	-	1	1	-	-	-	-	-

- Agents mapped reflect the abundance of tree species that occur in each ecoregion; Maritime Coastal Rainforests have the greatest variety of damage agent types, polar ecoregions have the fewest.
- Hardwood and willow defoliators are most frequently mapped in the Boreal Intermontane and Alaska Range Transition regions.
- Of those ecoregions where forest damage has been mapped, bark beetles have been detected in every region except Kodiak Island. However, a sizeable spruce beetle outbreak occurred on Afognak Island (Kokiak Island region in the 1930.

STATUS OF INSECTS

INSECTS AS AGENTS OF DISTURBANCE

Insects are active and significant components of Alaska's ecosystems. Arctic/boreal insects are characterized by having few species and large population numbers. Boreal insects are opportunistic in their behavior. They respond quickly to changes in climate and the availability of food and breeding material. The spruce beetle, for example, responds quickly to large-scale blowdown, fire-scorched trees, and spruce injured by flooding. Large numbers of beetles can be produced in such breeding material, leading to potential outbreaks.

Spruce beetles are one of the most important disturbance agents in mature white spruce stands in south-central and interior Alaska. A variety of changes occur to forest resources when many trees are killed. In the long run these changes are biological or ecological in nature. There are also socio-economic consequences in the short-term that can be viewed as either positive or negative, depending on the forest resource in question. Some of the impacts associated with spruce beetle infestations include, but are not limited to:

1. Loss of merchantable value of killed trees: The value of spruce as saw timber is reduced within three years of attack in south-central Alaska due to weather checking and sap-rots. The value of beetle-killed trees as house logs, chips, or firewood continues for many years if the tree remains standing.

2. Long term stand conversion: The best regeneration of white and Lutz spruce and birch occurs on a seedbed of bare mineral soil with some organic material. Site disturbances such as fire, windthrow, flooding, or ground scarification provide excellent sites for germination and establishment of seedlings if there is an adequate seed source. However, on some sites in south-central Alaska, grass and other competing vegetation quickly invade the sites where spruce beetles have "opened up" the canopy. This delays re-establishment of tree species. Regeneration requirements for Sitka spruce are less exacting; regeneration is thus, less problematic.

3. Impacts to wildlife habitat: Wildlife populations, which depend on live, mature spruce stands for habitat requirements may decline. We expect to see decreases in red squirrels, spruce grouse, Townsend Warblers, and possibly Marbled Murrelet populations. On the other hand, wildlife species (moose, small mammals and their predators, etc.) that benefit from early successional vegetation such as willow and aspen may increase as stand composition changes.

4. Impacts to scenic quality: Scenic beauty is an important forest resource. It has been demonstrated that there is a significant decline in public perception of scenic quality where spruce beetle impacted stands adjoin corridors such as National Scenic Byways. Maintaining or enhancing scenic quality necessitates minimizing impacts from spruce beetle infestations. Surveys have also shown that the public is evenly divided as to whether spruce beetle outbreaks damage scenic quality in backcountry areas.

5. Fire hazard: There is concern that fire hazard in spruce beetle impacted stands will increase over time. After a spruce beetle outbreak, grass or other fine vegetation increases; fire spreads rapidly through these vegetation types. As the dead trees break or blow down (5-10 years after an outbreak), large woody debris begins to accumulate on the forest floor. This material (boles) is the largest component of the fuels complex. Heavy fuels do not readily ignite, but once ignited they burn at higher temperatures for a longer period. The combination of fine, flashy fuels and abundant large woody debris results in a dangerous fire behavior situation. Rate of fire spread may increase as well as burn intensity. Observations from recent fires on the Kenai Peninsula have shown an increase in crown fires. This fire behavior is caused by fire traveling up the dead spruce trees and spotting into the crowns of adjacent beetle killed trees.

6. Impact to fisheries: If salmon spawning streams are bordered by large diameter spruce and these trees are subsequently killed by spruce beetles, there is a concern as to the future availability of large woody debris in the streams. Large woody debris in spawning streams is a necessary component for spawning habitat integrity.

7. Impact to watersheds: Intense bark beetle outbreaks can kill large amounts of forest vegetation. The "removal" of significant portions of the forest will impact to some degree the dynamics of stream flow, timing of peak flow, etc. There have been no hydrologic studies in Alaska quantifying or qualifying impacts associated with spruce beetle outbreaks. Impact studies, however, have been done elsewhere. In Idaho watersheds impacted by the Mountain Pine Beetle, there was a 15% increase in annual water yield, a 2-3 week advance in snowmelt, and a 10-15% increase in low flows.

There are a variety of techniques that can be used to prevent, mitigate, or reduce impacts associated with spruce beetle infestations. However, before pest management options can be developed, the resource objective(s) for a particular stand, watershed, landscape, etc. must be determined. The forest manager must evaluate the resource values and economics of management actions for each stand in light of management objectives. The beetle population level must also be considered because population levels will determine the priority of management actions and the type of strategy to be invoked. The key to forest ecosystem management is to manage vegetation patterns in order to maintain species diversity, both plant and animal, while providing for a multitude of resources such as recreation, fisheries, wildlife, and the production of wood fiber. Properly applied silvicultural practices as well as fire management in south-central and interior Alaska, can maintain the forest diversity needed to provide the range of products and amenities available in the natural forest for now and in the future.

* The number following place names refer to ecosystem section designations. Refer to page 7 and Appendix D.

BARK BEETLES

Spruce Beetle

Dendroctonus rufipennis Kirby

Aerial surveys conducted this year demonstrated a continuation of the downward trend in spruce beetle damage in terms of new and active infestation acres mapped. Statewide aerial surveys detected **86,038** acres of new spruce beetle activity in 2000. Since the peak of 1.1 million acres in 1996, new spruce beetle activity has decreased by 92%. Figure 3 shows the rise and fall of annual spruce beetle acres since 1990. The 86,038 acres mapped in 2000 is the lowest recorded acreage in more than 20 years.

Figure 4, on the following page, shows how yearly aerial survey mapping totals compare over four regionals. Although figure 4 only depicts acres since 1994, the Kenai Peninsula and Copper River regions have, respectively, accumulated 1,400,000,and 650,000 acres of spruce beetle infestations since 1991. Total cumulative acreage for all spruce beetle outbreaks during the last 10 years in Alaska is approximately 2.9 million acres.

The overall decline in new spruce beetle activity the past few years is a common trend in areas that are now

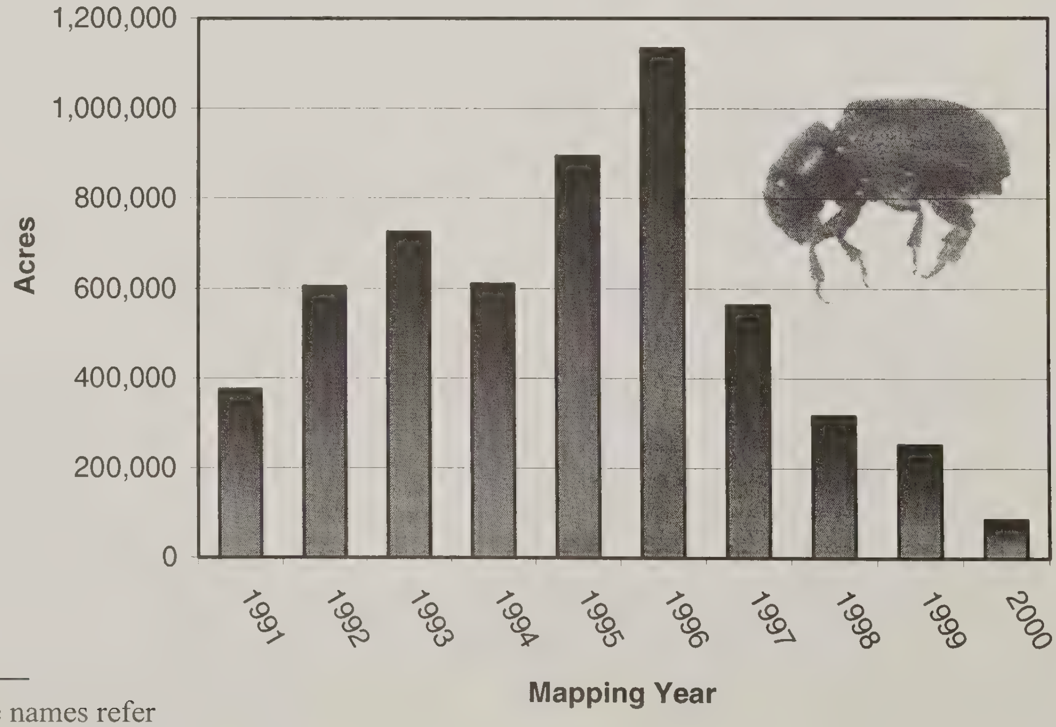


Figure 3. Alaska Region Spruce Beetle Activity (1991-2000)

depleted of large-diameter spruce host material. However, spruce beetle infestations are still active in many areas of the state, though at a much smaller scale, generally in areas that were previously undisturbed and adjacent to ongoing infestation centers. Spruce beetle populations are expected to persist in these same areas for several more years until a combination of weather conditions, lack of suitable host material, or other disturbance (e.g., timber harvest) occur to significantly reduce beetle populations. As these changes occur, spruce beetle populations will continue to persist at more normal, endemic levels in these same forest areas unless some type of disturbance occurs which increases beetle populations to epidemic levels, such as a wind event (stem breakage and blowdown), wildfire, or some other factor that would favor beetle buildup (e.g., tree stress or favorable conditions for beetle dispersal). Areas that have already been severely impacted, such as on the mainland Kenai Peninsula, no longer contain a significant component of live, mature spruce to sustain bark beetle outbreaks of any magnitude. They will remain at moderate to high risk for potential catastrophic wildfire over the next 5-15 years and possibly longer.

Most areas that sustained active spruce beetle infestations in the current statewide outbreak have been reduced to endemic population levels. A few areas still have active infestations even though mapped acres are insignificant compared to the acreage mapped the last few years. For example, localized infestations were mapped in 2000 in the Copper River Valley from Glennallen to McCarthy (B8), Iliamna Lake (m7), Lake Clark and vicinity (B3), the northern part of the Kenai Peninsula, the east end of Kachemak Bay on the southern Kenai Peninsula (M6), the Matanuska-Susitna Valley, and along the Anchorage Hillside (B5). Spruce beetle activity on the Chugach National Forest has declined for the third year, and by 84% from 1999 totals (from 16,500 ac to 2,650 ac; Seward (M6) quadrangle). Areas with the most intense beetle pressure in south-central Alaska include the west end of the south-side Kachemak Bay from Sadie Cove to Seldovia (M6), a narrow coastal band extending up to 4 miles inland between Ninilchik and Homer and a small area of intense activity in the vicinity of Beluga River on the west side of Cook Inlet (B5).

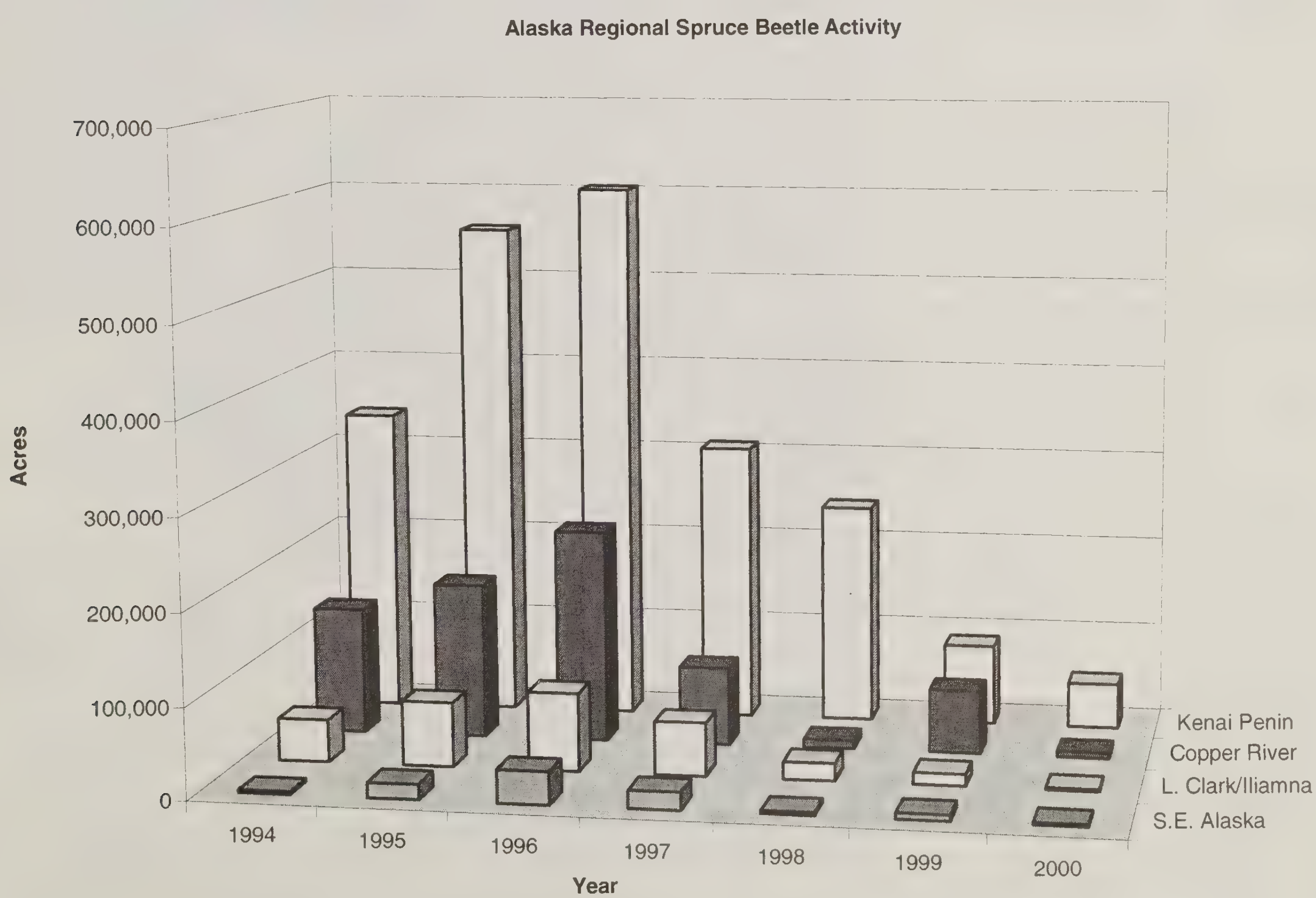


Figure 4. Regional spruce beetle activity since 1994. Note the unusual low in 1998 for the Copper River region was due to poor aerial survey visibility from weather and smoke.

Spruce beetle activity on the northern portion of the Kenai Peninsula remains static. For comparison, spruce beetle activity sketchmapped in the Kenai quadrangle was 42,100 acres in 1999 versus 30,300 acres of new activity acres mapped in 2000. Beetles continue to be active along the ridge areas above and north of Homer to Anchor Point (B5). Beetle populations, however, in the lower elevation stands in and around Homer have collapsed with most of these pure stands having more than 90% tree mortality. No new beetle activity was observed east of Homer to the Fox River at the head of Kachemak Bay. Most of the coastal stands 1-2 miles inland from Ninilchik south to Homer have received heavy spruce beetle pressure the last 3 years as adjacent beetle populations have moved to the remaining susceptible spruce habitat. On the south side of Kachemak Bay (M6), spruce beetles still remain active from the east side of Tutka Bay all the way to Seldovia. Beetle activity in the Seldovia quadrangle, which encompasses most of the southern tip of the Peninsula and southside Kachemak Bay to Seldovia areas, went from 30,900 acres in 1999 to 18,900 acres of new infestations in 2000. Beetle activity on the east end of Kachemak Bay in China Poot Bay, Halibut Cove, Mallard Bay, to Bradley Lake has essentially run its course. Most of these stands now have significant amounts of spruce stem breakage from wind damage. Overall, Kenai Peninsula spruce beetle activity has decreased from 49,200 in 1999 ac to 73,000 ac in 2000; a 33% decrease).

Active spruce beetle infestations continued in 2000 in west-side Cook Inlet stands within Kenai Peninsula Borough, State of Alaska, and Alaska Native regional corporation ownerships. New infestation decreased significantly to 3,700 acres mapped versus 40,100 acres in 1999 (Tyonek (B5) quadrangle area). Most of the continuing and new beetle activity was observed north of Tyonek, between the Beluga River drainage and Little Mt. Susitna (2300 ac), with scattered small spots of new activity along the coastal lowlands between Beluga, and easterly toward Anchorage. The long-infested stands between Tyonek and Tuxedni Bay did not show visible, new spruce beetle activity and are now composed of 90+% beetle-killed spruce. Previously mapped spruce beetle infestations located in the vicinity of Big River Lakes and the entrance to Lake Clark Pass have essentially run their course, with beetles having killed the majority of the spruce host type. The majority of the remaining spruce stands on the west side of Cook inlet, which have been under beetle attack for the past several years, are in similar condition. The beetles have eaten themselves out of "house and home".

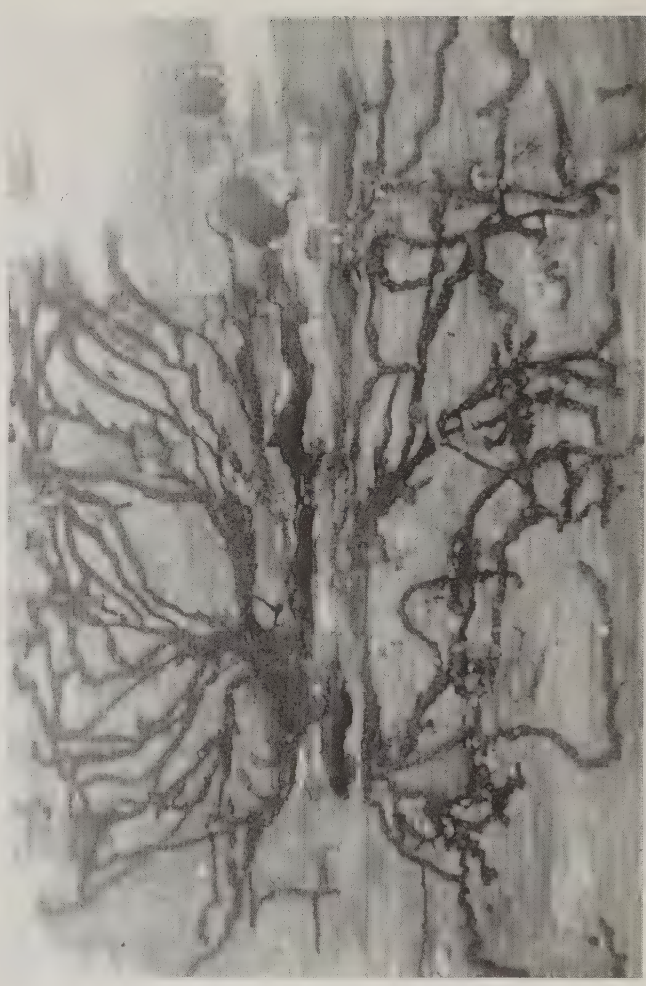


Figure 5. Bark beetle galleries.

In the Lake Clark area on the west side of the pass and southwesterly toward Lake Iliamna spruce beetle activity has decreased about 82% from 1999 levels. This is evidenced by approximately 12,700 acres mapped in 1999 vs. 2,300 acres this year (Lake Clark and L. Iliamna quadrangles). Nonetheless, spruce beetle activity increased in 2000 along the northeast corner and east side of Iliamna Lake (B3) to 2,250 acres mapped from 610 acres in 1999. Most of the Lake Iliamna activity (1600 ac) is occurring near the village of Pedro Bay. The Lake Clark and Iliamna Lake spruce beetle outbreaks were first observed in 1992, peaking at approximately 85,200 acres in 1996.

Continued spruce beetle activity, especially in the Iliamna and Lake Clark regions is of concern to resource managers and will be monitored over the next several years. There remain several areas of contiguous, mature spruce host type in this region that have not sustained any appreciable spruce beetle infestation during the decade of the current epidemic. These areas have the potential for large spruce beetle outbreaks given a future change in local climatic conditions or a disturbance event (e.g., blowdown, top breakage, etc.). Significant forest resource values such as aesthetics, impacts to wildlife habitat and

populations, and subsistence use could be affected by a massive spruce beetle outbreak in this region similar to the Kenai Peninsula and Copper River outbreaks. Close monitoring of the mature spruce forests in this region is warranted.

The Susitna valley remains static in numbers of new beetle infestations mapped this year with 800 acres compared to 1,500 acres mapped in the same areas in 1999 (Talkeetna & Talkeetna Mts. Quadrangles, B3). This is characteristic of the mixed spruce and birch stands growing throughout the MatSu Valley lake country that have a mosaic of age classes and stocking levels. Also characteristic is the location of most of this new beetle activity along the Susitna River and its tributaries which receive continuous river bank erosion and fallen, large-diameter, green spruce. Areas of fresh spruce blowdown continue to be the primary centers that will sustain increases of beetle populations above endemic levels. The epidemic is aided by favorable environmental conditions for beetle brood survival and adult dispersal.

Similar to 1999 surveys, Copper River area spruce beetle activity is concentrated east of the Richardson Highway near Copper Center and north of the Copper River between Chitina and McCarthy. Approximately 5,500 acres of active beetle infestation were mapped compared to 39,300 acres in 1999 (McCarthy quadrangle, B9). Most of this acreage is "light to moderate" in intensity and is concentrated primarily on National Park Service lands. Many of these stands have a significant component of black spruce, which is not as susceptible to beetle attack. The current infestation has been in progress for about 5-7 years and will probably persist at low to moderate levels for several more years due to the extensive acreage of this mixed white/black spruce type. Finally, the areas of beetle activity that were observed in 1999 along the Hanagita and Bremner (M6) river drainages east of Valdez were flown again this year and found to be inactive in terms of visible "red-topped" spruce in 2000. It appears that the infestations in those areas were active for about 3-4 years and the available habitat of mature, susceptible spruce have succumbed to the spruce beetle.

New spruce beetle activity within the Municipality of Anchorage (B5) along the Eagle River and Anchorage hillside areas was almost nonexistent in 2000 based on general observations of the forest specialists that have tracked this activity. Specific acreage of new beetle activity is minor. An intense aerial or ground infestation survey was not conducted of the Anchorage Bowl areas during 2000. The University of Alaska Cooperative Extension Service reported concentrations of new beetle activity above Potter Marsh and along Birch and Campbell Airstrip roads, on the lower Anchorage Hillside and scattered pockets of activity in Eagle River. Private landowner reports received throughout the summer indicate that discrete pockets of moderate to heavy beetle activity persist mainly in "islands" of mature spruce adjacent to infested areas. These spruce islands have received heavy pressure from the large beetle populations of the last few years and may have been aided by local wind events which dispurse beetles into new areas. Since 1990, approximately 85,000 acres of cumulative infestation have been mapped within the Anchorage municipal boundary (MOA). About forty percent is distributed within the greater Anchorage area including Fire Island

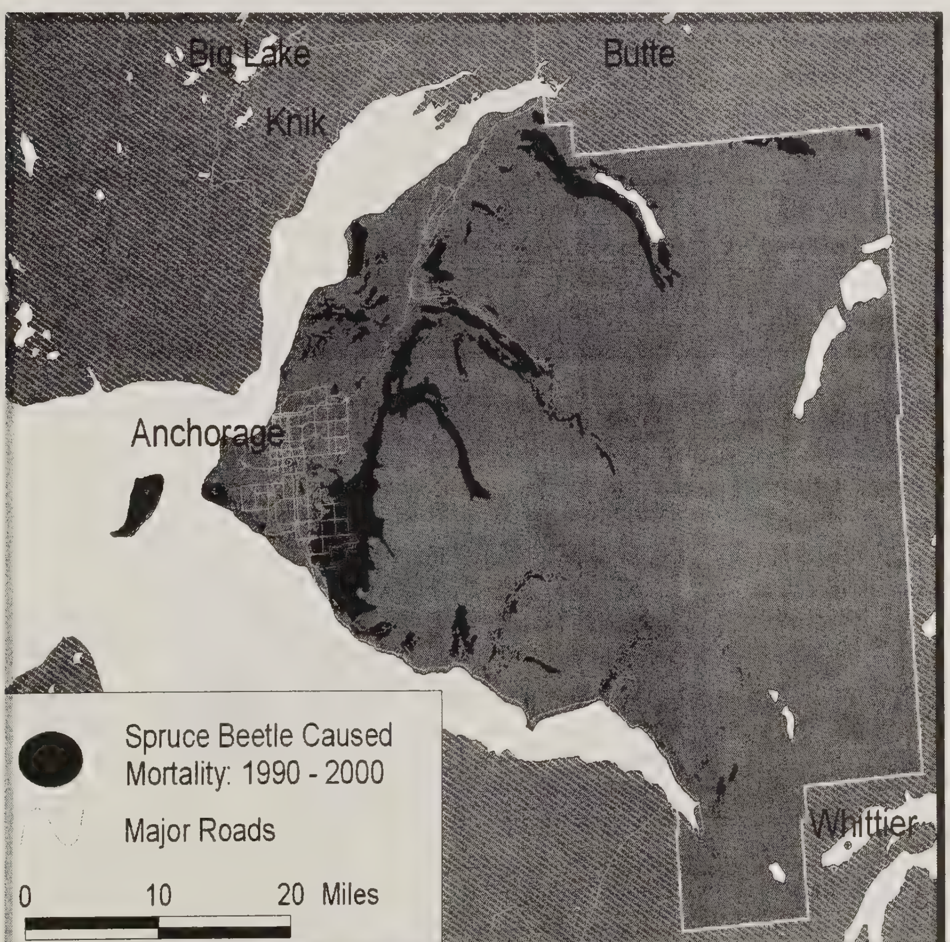


Figure 6. Spruce beetle caused mortality in the Anchorage Municipality since 1990 is shown in Black. Mortality in areas sourounding the municipality are not shown.

and the Hillside areas (35,000 ac). Some activity has occurred along the north side of Turnagain Arm south to the Portage valley (4,000 acres); the remaining infestation activity over this 11-year period has been mapped in and along the Eagle River hillside and Valley (14,000 ac), Eklutna Lake and Valley (16,000 ac), and the Knik River Valley (18,000ac). Current management activities within the infestation areas have centered on the development of wildfire and fire hazard management plans by the local fire fighting and resource agencies and include the formation of cooperative partnerships, identification of protection corridors, and project work to reduce fuels loading at strategic initial attack points.

Scattered spruce beetle activity still persists along the Kuskokwim River downstream from McGrath and along Big River. Beetle activity increased to 4,700 acres from 1,200 acres mapped in 1999 (+292%; McGrath quadrangle). Beetle populations remain active near Sleetmute, on the lower Kuskokwim, but have decreased 45% from 1999 levels (1000 ac vs. 1,800 ac; Sleetmute quadrangle). Small-scale logging operations and localized flooding events have probably contributed to this past activity although periodic wildfires in these interior areas help mitigate expansion of these localized outbreaks. Interestingly, an area east of Nome near Elim on the south-side Seward Peninsula was checked for beetle activity by special request and 3,700 acres of new beetle activity were observed (Solomon quadrangle). The Elim infestation appeared to have been active for several years and had previously been visited about 9 years ago. Mapping of beetle activity in the more remote areas of the Alaska interior is a continuing challenge due to changing weather, periodic smoke, which affects survey visibility, and other logistical issues that make yearly comparisons difficult. However, continued monitoring of these areas is critical to establish baseline information that is important for determining forest health trends and the overall condition of Alaska's forests.

Spruce beetle activity in southeast Alaska's Sitka spruce forests declined to 2,700 acres in 2000 vs. 6,500 acres in 1999 and from a peak of 35,700 acres in 1996 (93% decrease). Current spruce beetle activity continues in areas that were infested in 1999, and is concentrated in the Skagway quadrangle along the upper Chilkat River near Tihitkah Mountain (1,200 ac), in the Yakutat quadrangle within Glacier Bay National Park and Preserve, and Tongass N.F. lands along the Alsek River at Dry Bay (1,200 ac) and Deception Hills at the head of the Grand Plateau Glacier (400 ac).

To summarize, spruce beetle activity in Alaska has decreased significantly since the peak year of 1996. New spruce beetle activity is occurring in stands composed of pure spruce with few hardwoods interspersed in the canopy. Entomologists anticipate that beetle activity will continue in the major outbreak area of the Kenai Peninsula for several more years until the mature, spruce host type is depleted. New and smaller localized outbreaks are expected, however, if climatic and stand conditions become favorable in areas that have been previously infested. For the last 3 years, climatic trends have cycled to a more cool and wet summer pattern for south-central and interior Alaska, and are less favorable for spruce beetle population buildup. Spruce beetle populations are expected to remain at endemic levels for several years unless the current climatic patterns shift. Past bark beetle outbreak areas will be monitored closely over the next 2-3 years especially on the southern Kenai Peninsula, lower Copper River region between Valdez and Glennallen, the Iliamna and Lake Clark regions, and along the major interior Alaska river systems such as the Yukon, Kuskowim and Tanana that are periodically subject to flooding, erosion, and siltation disturbances.

Engravers

Ips perturbatus Eichh.

Engraver activity increased by 505% from approximately 3,800 acres in 1999 to 23,000 acres detected from 2000 aerial surveys. The bulk of this activity is concentrated in interior Alaska where *Ips* infestations occur primarily along river floodplains and areas disturbed by past erosion, spruce top breakage (e.g., snow loading), harvest, or wind. Most *Ips* activity is very localized and can be distinguished from spruce beetle damage by dying and reddening upper crowns in mature spruce. *Ips* are often associated with spruce beetle in the same general areas, however, *Ips* typically respond faster than spruce beetle in these areas since they are a more aggressive bark beetle in keying in to host stresses and nutrient changes brought on by these various disturbances. *Ips* activity in 2000 is noted in table 4 by USGS quadrangle location (1999 activity, for these quads, if any, is also noted):

Table 4. Engraver activity

USGS Quad	Acres 2000	1999
Bettles	118	
Charley River	108	169
Circle	228	35
Fairbanks	29	8
Ft. Yukon	81	106
Holy Cross	12,222	16
Hughes	20	
Kantishna River	23	773*
Medfra	47	61*
Russian Mission	5,408	
Shungnak	55	20
Sleetmute	4,522	11
Survey Pass	47	
Tanacross	8	
Tanana	15	3
Taylor Mts.	62	
Wiseman	7	86

* mapped as "IPB" (*Ips* and spruce beetle)

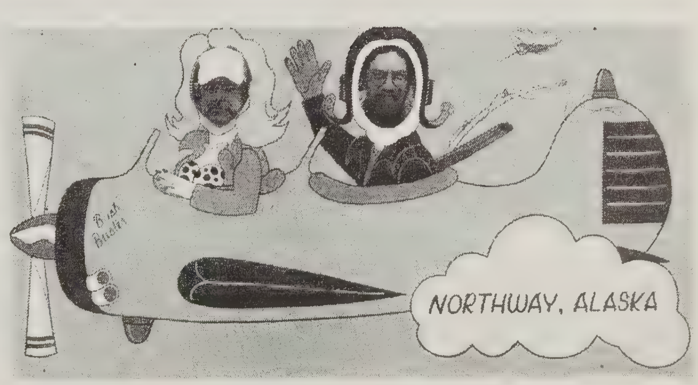
Because of the difficulty in separating *Ips* and spruce beetle activity when both occur in a stand it is often necessary to conduct periodic ground checks to determine the primary mortality agent. The shorter life cycle of the *Ips* beetle can help populations build quickly in the tops of spruce trees also infested by spruce beetles. On the Kenai Peninsula, this dual association has been particularly challenging in cutover areas when spruce slash has been left on the ground following harvest or a significant component of smaller diameter spruce remain on site after harvest. If enough suitable brood material remains, *Ips* numbers can increase to levels large enough to infest standing, healthy trees. Ground surveys were initiated in 2000 to determine how bark beetles in general have impacted residual spruce in both harvested and unharvested stands on the Kenai Peninsula. One objective of the "*Ips* survey" project is to determine the importance of *Ips* populations in driving the current spruce beetle epidemic.

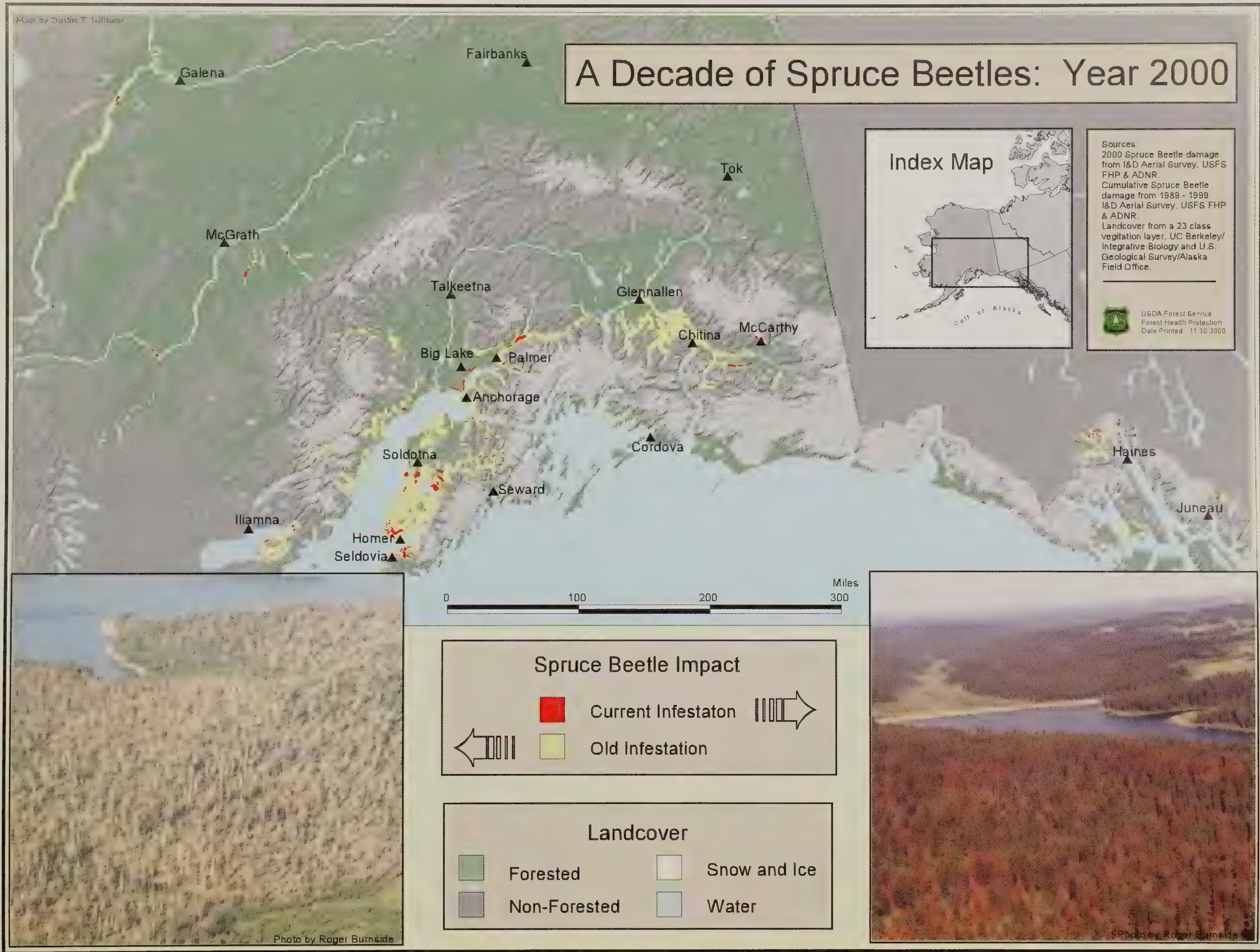
Aerial surveys can provide estimates of year-to-year trends in total *Ips* activity and relate this activity to localized host disturbance events. This information can be an important component of establishing overall forest health and pest monitoring trends that would be used to guide forest management activities. Refer to the fold out map 5, General Forest Pest Activity, for general locations of *Ips* activity mapped in 2000.

Miscellaneous Bark Beetles

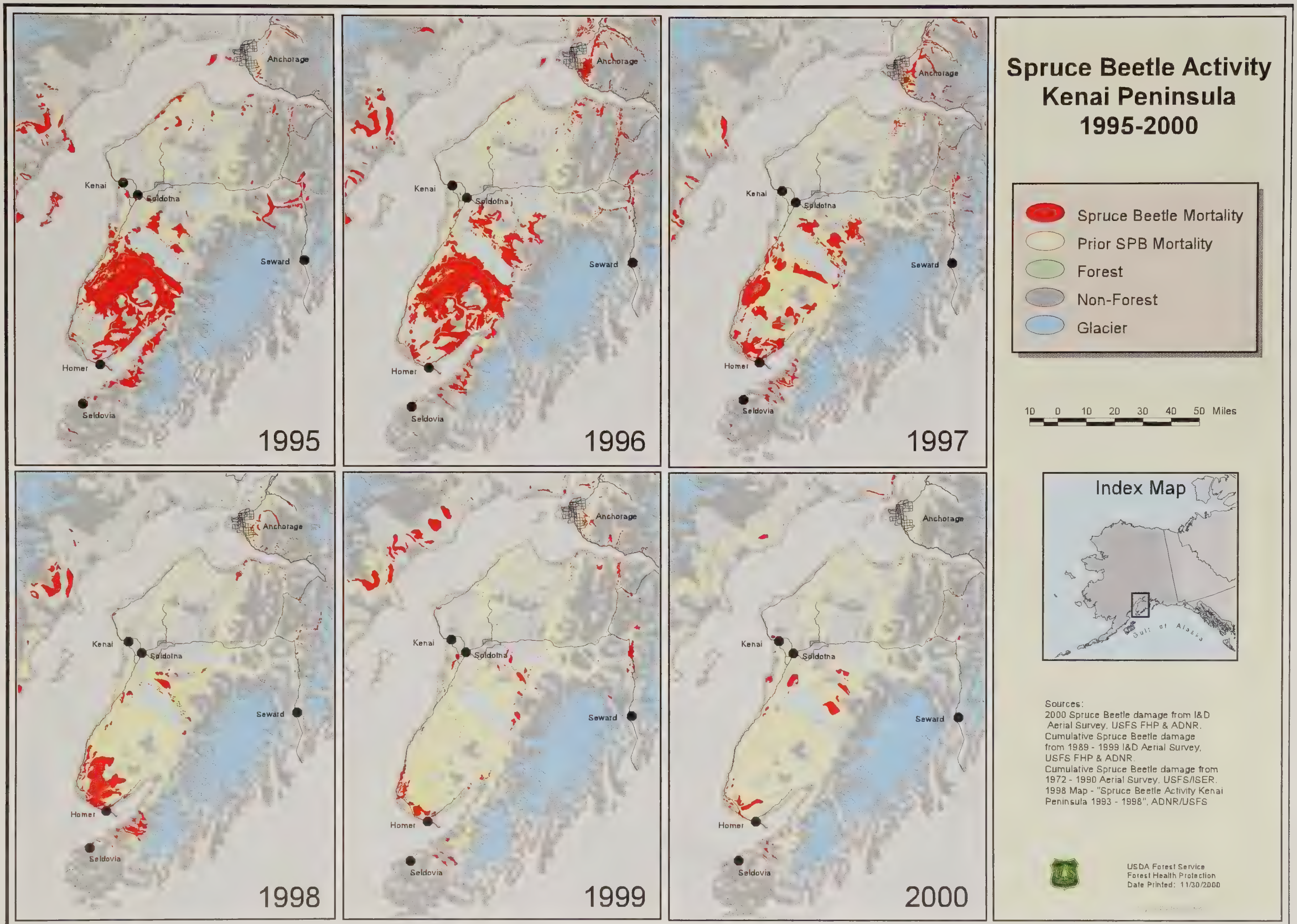
Pityophthorus nitidulus (Mannerheim)
Polygraphus rufipennis (Kirby)

These secondary bark beetles of the family Scolytidae are commonly found breeding in dead and dying spruce in Alaska and are not noted as tree killers. These two scolytidas, however, were responsible, in part, for the death of more than 40 recently planted Colorado blue spruce in the Anchorage Bowl (B5). The trees were imported from Idaho and were experiencing transplant shock from having their large woody roots severed.





Map by Dustin T. Wittwer
A Decade of Spruce Beetles: Year 2000
Fairbanks
Galena
McGrath
Talkeetna
Tok
Glennallen
Chitina
McCarthy
Big Lake
Palmer
Anchorage
Cordova
Soldotna
Seward
Iliamna
Homer
Seldovia
Haines
Juneau
Index Map
Gulf of Alaska
Sources:
2000 Spruce Beetle damage from I&D Aerial Survey, USFS FHP & ADNR.
Cumulative Spruce Beetle damage from 1989 - 1999 I&D Aerial Survey, USFS FHP & ADNR.
Landcover from a 23 class vegitation layer, UC Berkeley/ Integrative Biology and U.S. Geological Survey/Alaska Field Office.
USDA Forest Service
Forest Health Protection
Date Printed 11 30 2000
Miles
0
100
200
300
Spruce Beetle Impact
Current Infestaton
Old Infestation
Landcover
Forested
Non-Forested
Snow and Ice
Water
Photo by Roger Burnside
Photo by Roger Burnside


Spruce Beetle Activity
Kenai Peninsula
1995-2000
Spruce Beetle Mortality
Prior SPB Mortality
Forest
Non-Forest
Glacier
10 0 10 20 30 40 50 Miles
Index Map
Gulf of Alaska
Sources:
2000 Spruce Beetle damage from I&D Aerial Survey, USFS FHP & ADNR.
Cumulative Spruce Beetle damage from 1989 - 1999 I&D Aerial Survey, USFS FHP & ADNR.
Cumulative Spruce Beetle damage from 1972 - 1990 Aerial Survey, USFS/ISER.
1998 Map - "Spruce Beetle Activity Kenai Peninsula 1993 - 1998", ADNR/USFS
USDA Forest Service
Forest Health Protection
Date Printed: 11/30/2000
1995
1996
1997
1998
1999
2000
Anchorage
Kenai
Soldotna
Seward
Homer
Seldovia

DEFOLIATORS

SOUTHEAST ALASKA DEFOLIATOR PLOTS

Fewer defoliator plots (32 plots) were visited during the 2000 aerial survey than in previous years (52 plots) throughout southeast Alaska. An effort was made to distribute these plots evenly across the archipelago.

Larval counts can be used as a predictive tool for defoliator outbreaks. The total count for all insects in 2000 was only about one-half of that in 1999 which indicates that hemlock sawfly is not at outbreak numbers. Hemlock sawfly counts were higher for some plots in 2000 than in 1999. The highest sawfly larval count was from the plot in Thorne Bay (M4), more than twice the number of larvae counted at the other eleven locations.

Figure 7. Progression of top-kill following repeated budworm defoliation.

Spruce Needle Aphid

Elatobium abietinum Walker

Spruce needle aphids feed on older needles of Sitka spruce, often causing significant amounts of needle drop (defoliation). Defoliation by aphids cause reduced tree growth and can predispose the host to other mortality agents, such as the spruce beetle. Severe cases of defoliation alone may result in tree mortality. Spruce in urban settings and along marine shorelines are most seriously impacted. Spruce aphids feed primarily in the lower, innermost portions of tree crowns, but may impact entire crowns during outbreaks. Outbreaks in southeast Alaska are usually preceded by mild winters.

Following the mild winter of 1991-92, spruce needle aphid populations expanded rapidly in southeast Alaska, causing over 25,000 acres of Sitka spruce defoliation. Populations crashed in 1993 due to extended periods of sub-freezing temperatures during January and February. After a slight resurgence of activity in 1994, the 1995 population levels were low. Another outbreak occurred in 1998 following another mild winter, resulting in 46,300 acres of defoliation. Southeast Alaska accounted for 44,300 acres with 39,100 of those acres on national forest lands.

In 2000, 39,400 acres of defoliation were detected, almost as many acres as in 1998. Seventy-five percent of these acres (29,500 acres) were on national forest lands (M4). The defoliation in 2000 was primarily on south to west facing slopes.

Western Black-Headed Budworm

Acleris gloverana Walsingham

The black-headed budworm is native to the forests of coastal and southwestern Alaska. It occurs primarily in southeast Alaska and has been documented there since the early 1900's. Budworm populations in Alaska have been cyclic, arising quickly, impacting vast areas, and then subsiding within a few years.

In southeast Alaska, a peak year for budworm defoliation occurred in 1993, totaling 258,000 acres. The last budworm outbreak of this magnitude occurred from the late 1940's to mid-1950's. Cool-wet weather in early summer months retards the growth and development of the budworm and may have resulted in population declines. Black-headed budworm populations crashed in 1995. In 1998, 1999, and 2000 no budworm defoliation was aerially detected.

Hemlock Sawfly

Neodiprion tsugae Middleton

Hemlock sawfly, a common defoliator of western hemlock, is found throughout southeast Alaska. Historically, sawfly outbreaks in southeast Alaska have been larger and of longer duration in areas south of Frederick Sound (M4). In 1999, sawfly defoliation was virtually nonexistent, this coming after a peak in 1997 when 2,500 acres were recorded.

In 2000, most of the 5,200 acres of activity occurred in “hot spot locations”(M4) in Kasaan Bay, Prince of Wales Island, Burroughs Bay north of Ketchikan, and Windham Bay east of Admiralty Island.

Unlike the larvae of the black-headed budworm, hemlock sawfly larvae feed in groups, primarily on older hemlock foliage. These two defoliators, feeding in combination, have the potential to completely

defoliate western hemlock. Heavy defoliation of hemlock by sawflies is known to cause reduced radial growth and top-kill. Hemlock sawflies may ultimately influence both stand composition and structure. The sawflies themselves are a food source for numerous birds, other insects, and small mammals.

Spruce Budworm and Coneworm

Choristoneura fumiferana (Clemens)
Choristoneura orae (Freeman)
Dioryctria reniculelloides Mutuura & Munroe
Zeiraphera spp.

In 2000, approximately 40,844 acres of lightly defoliated spruce was concentrated in one area along the Christian River approximately 25 miles north of Fort Yukon, extending nearly 18 miles (B2,B6). The spruce defoliation could be caused by either the eastern spruce budworm, coneworm, or bud moth; however, ground verification was not done. This area will be flown again in 2001 and the insect identified if possible.

It appears that after more than five consecutive years, the budworm/coneworm outbreak along the Yukon River has ended probably due to the increasing effects of parasites and predators. We expect little defoliation next year. A ground survey, conducted in late summer of 1999 by Tanana Chief Council crews, noted no mortality associated with the budworm/coneworm outbreak, although top-kill was prevalent. Little *Ips* spp. activity was noted in previously defoliated spruce stands.

Larch Sawfly

Pristiphora erichsonii (Hartig)

Total area of land affected by the larch sawfly in 2000 was 64,859 acres; a significant reduction from the more than 190,000 acres of defoliated larch observed in 1999.

The area of most intense activity remains the vast area between McGrath and the Alaska Range (B10). After eight years of heavy defoliation, larch mortality is now occurring throughout the range of larch in Alaska. The concern still exists that larch beetle may begin to build up in these heavily defoliated stands which could result in further mortality. The Alaska Cooperative Extension Integrated Pest Management Technicians noted localized defoliation of Siberian larch in the Mat-Su Valley and Anchorage Bowl for the second consecutive year (B5). This is the first time the sawfly has been recorded south of the Alaska Range and no doubt represents an accidental introduction. Efforts are being undertaken to eradicate this pest from these areas as Siberian larch is widely used as an ornamental in urban settings.

Figure 8. Larch sawfly larva

Aspen Leaf Miner

Phyllocnistis populiella (Chambers)

Widespread, intensive defoliation of aspen by the aspen leaf miner was noticeable throughout interior Alaska, especially from the Tanana Valley north to Eagle and west into the Yukon Territory, Canada (B13, B15).

Meandering larval mines are produced in the epidermal layers on the undersides of leaves. Such mining reduces the photosynthetic area of the affected leaves. Heavy repeated attacks reduce tree growth and may cause some top-kill.

Figure 9. Note the leaf miner's meandering pattern on this aspen leaf.

Adult moths overwinter under bark scales of aspen. Adults emerge in early June and deposit eggs singly on the leaf edge then slightly fold the leaf to form a protective covering for the egg until larval emergence.

The newly hatched larvae bore into feed between epidermal leaf tissues. Pupation occurs within the larval leaf mines. Adult emergence occurs prior to or sometimes after the leaves drop in late August and September.

Birch Defoliation

Fenusa pusilla (Lepeletier)

For the fourth consecutive year, birch defoliation was very noticeable in the Anchorage Bowl (B5) from late July to August. Although these hardwoods have been defoliated for several consecutive years, as yet there doesn't appear to be any lasting damage.

The birch leafminer was first reported in eastern United States in 1923. Introduced from Europe, it has spread rapidly throughout the northern United States, Canada, and Alaska. The adult sawfly is black, about 3 mm long, and similar in appearance to a common fly. Larvae overwinter in cocoons in the soil and adults appear in the spring when the first birch leaves are half grown. The female sawfly deposits her eggs singly on newly developing leaves. At times, almost every leaf is mined by the developing larvae, giving it a brown color. When mature, the larva cuts a hole through the leaf and drops to the ground. There the larvae build a cell in which pupation takes place; 2-3 weeks are usually required for transformation into the adult stage. A re-flushing of leaves may occur, and a second generation of egg-laying sawflies may develop. Two to four generations of this insect can develop in northeastern US; the number of generations in Alaska is not known.

Large Aspen Tortrix

Choristoneura conflictana Wlkr.

Throughout Alaska, tortrix defoliation of aspen declined for the second year in a row to only 5,576 acres, down from 13,336 acres in 1999. This decline is consistent with the cyclic nature of these insects.

The most active populations affected approximately 4,300 acres with moderate to light defoliation near Nenana along and south of the Tanana River (B10). Approximately 1,100 acres of moderate defoliation occurred along the Dalton Highway (B2) between Bettles and the Yukon River.

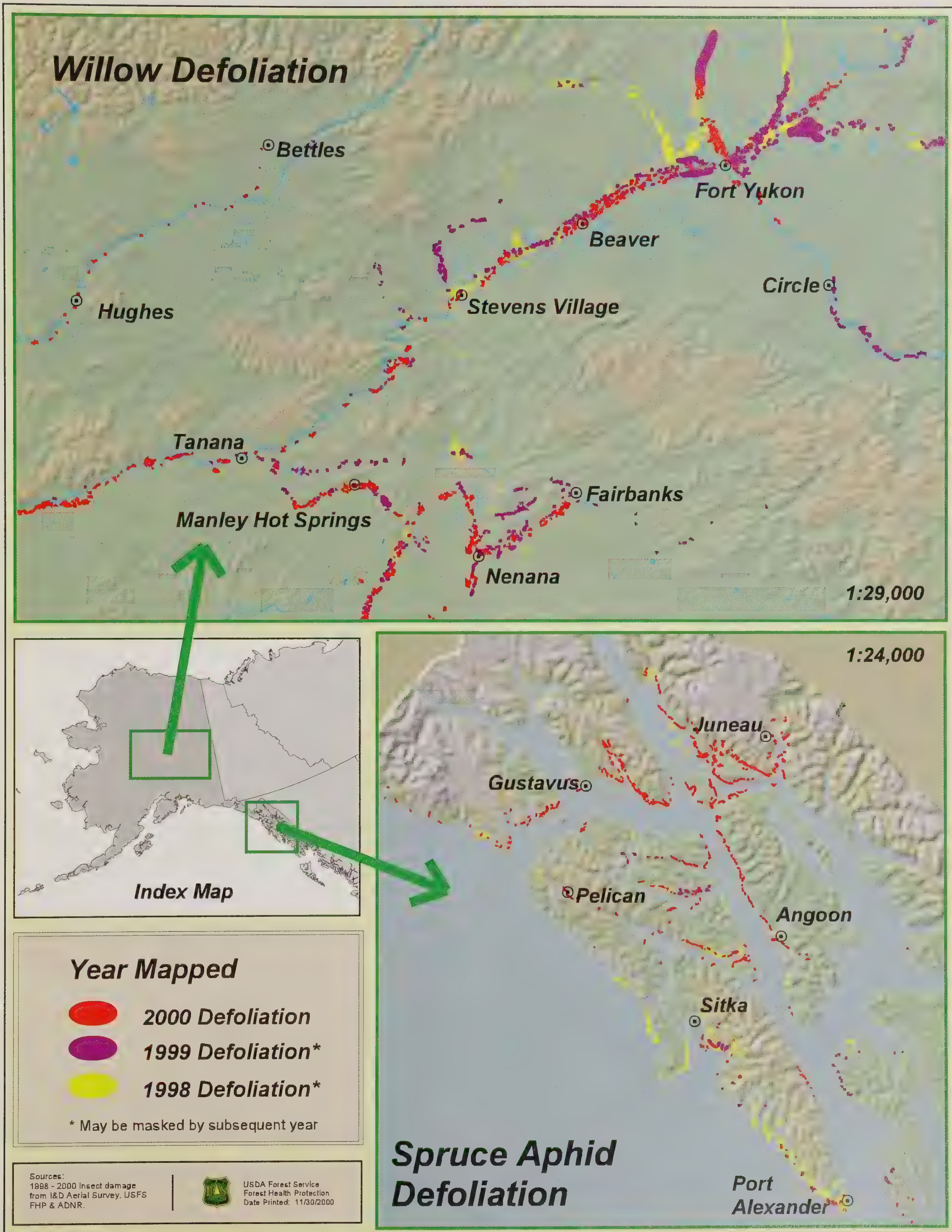
Historically, populations of tortrix tend to cycle over time in response to environmental conditions. The consistent trend is a pattern of one to two years of increasing activity followed by two to three years of decline. Weather, starvation and parasites are the most important factors in precipitating these declines. It is difficult to make predictions about future populations of this insect.

Cottonwood Defoliation

Chrysomela spp.
Epinotia solandriana L.

Cottonwood defoliation by the cottonwood leaf beetle was barely noticable throughout south-central and interior Alaska. Only three spots were noted during the 2000 survey. One area, 119 acres, was on Big River (B10) south of McGrath. The second area, 97 acres, was on the Skwentna River near Shell Lake; and the third area, 28 acres, was on the Susitna River just south of Susitna (B5).

In Southeast Alaska, the majority of cottonwood defoliation on the southern end of Russell Fiord near Yakutat was attributed to a leaf roller. The leaf roller contributed over 5,100 acres of cottonwood defoliation and over 4,900 acres of alder defoliation, also in Russell Fiord


Willow Defoliation
Bettles
Fort Yukon
Beaver
Hughes
Circle
Stevens Village
Tanana
Fairbanks
Manley Hot Springs
Nenana
1:29,000
1:24,000
Juneau
Gustavus
Pelican
Angoon
Sitka
Index Map
Spruce Aphid Defoliation
Port Alexander
Year Mapped
2000 Defoliation
1999 Defoliation*
1998 Defoliation*
* May be masked by subsequent year
Sources:
1998 - 2000 Insect damage from I&D Aerial Survey, USFS FHP & ADNR.
USDA Forest Service
Forest Health Protection
Date Printed: 11/30/2000

Willow Leaf Blotchminer

Micrurapteryx salicifolliela (Chambers)

The outbreak of the willow leaf blotchminer continued in 2000. This year, defoliation was reported on 36,002 acres vs. 180,396 acres noted in 1999. The acreage figure is rather deceiving considering the range of damage. Blotchminer activity covers both the Yukon and the Tanana River drainages and their tributaries from the Canadian border to McGrath and Holy Cross (B2, B3, B6, B7, B10, B12, B13, B15). Most of the defoliation occurred between Ruby and Ft. Yukon, 22,412 acres, along the Yukon River (B2, B6, B7) and from Tanana to Fairbanks, 4,293 acres along the Tanana River (B2, B7, B10, B13). Oftentimes, the brown-appearing, defoliated willow stretches as far as one can see from the air; however, cost prohibits more thorough coverage. Intensive willow mortality has been observed in the Yukon Flats area and the concern remains that this mortality may have a detrimental effect on availability of willow sprouts, upon which moose depend heavily as a food source. Prior to this outbreak, this insect was not identified in Alaska.

This insect has one generation per year with the pupal stage as the overwintering stage. Ten species of willows have been observed infested, the severity of which differed somewhat between localities and species. Feltleaf willow, *Salix alaxensis*, is not infested due to its under leaf surface being covered by a protective felt-like mat of hairs that prevents attachment of blotchminer eggs.

Gypsy Moth

Lymantria dispar (L.)

The European gypsy moth was accidentally introduced into the eastern U.S. in the late 1800's and has been responsible for considerable damage to the hardwood forests of the east. The gypsy moth has also been introduced to the western U.S. where millions of dollars have been spent on its eradication.

Since 1986, Forest Health Protection, in conjunction with Alaska Cooperative Extension and USDA APHIS, has placed gypsy moth pheromone monitoring traps throughout Alaska. To date, only two European gypsy moths have been trapped in Alaska. As far as we know, populations of the gypsy moth have not been established in Alaska. Due to the detection of the Asian gypsy moth (a more damaging race of the European gypsy moth) in the Pacific Northwest, more than 200 detection traps were placed throughout Alaska in 2000. No Asian or European gypsy moths were collected. If the Asian gypsy moth becomes established in the western U.S., including Alaska, the potential impacts to forest and riparian areas could be tremendous. The trapping program will be continued next year.

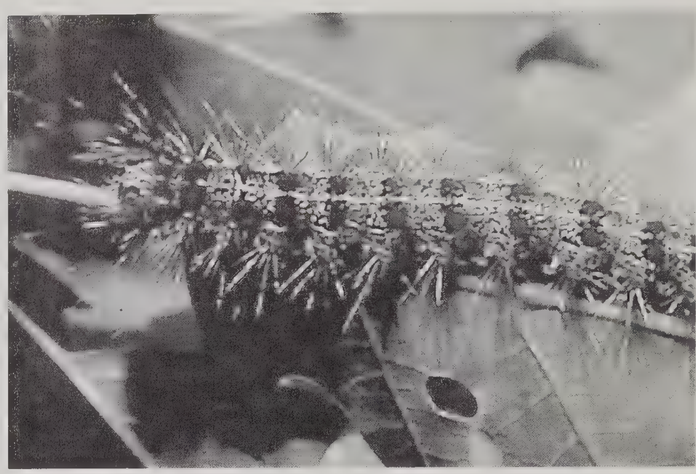


Figure 10. Gypsy moth larvae

Alder Woolly Sawfly

Eriocampa ovata (L.)

Moderate defoliation of Sitka and thinleaf alder was observed for the fourth consecutive year in many parts of the Anchorage Bowl (213B). Heavy defoliation was also observed throughout southeast Alaska on red alder. This sawfly is a European species now established throughout the northern U.S., Canada, and Alaska. The larvae are covered with a distinctive shiny, woolly secretion. They skeletonize the lower leaves on young alders; the upper crown is usually not fed upon. Populations are expected to decline next year as a result of this summer's cool and wet conditions.

Spider Mites: Acarina

***Paratetranychus* spp. and *Tetracychus* spp.**

Anchorage IPM Technicians (Alaska Cooperative Extension) noticed extensive damage to spruce trees from spider mite feeding for the second consecutive year. This damage was most visible in August and September. Infested trees showed signs of yellowing needles in a “flagging” pattern and green needles appeared dull in color with much webbing present. Some defoliated trees exhibited an overall decline in appearance and then dropped the faded needles. Weeks of warm, dry weather early in the spring may have contributed to the abundance of spider mites.

INVASIVE PESTS

Invasive pests (introduced non-indigenous plants, animals, and microbes) are among the most serious threats to biological diversity in Alaska. To date, few invasive pests have been introduced and established in Alaska. Of concern is the movement of organisms from the continental U.S. into Alaska in light of climate change and increased commerce. A warming trend can increase the probability that organisms accidently introduced into Alaska can become established.

It is inevitable that we are going to see more and more introduced pests arriving in Alaska. If we are not prepared to expend the efforts to safeguard our ecosystems, Alaska will be poorer in terms of resources and biological diversity. USDA APHIS, State of Alaska Division of Agriculture, Alaska Cooperative Extension, and the USDA Forest Service, Forest Health Protection already have small programs in place to detect these introductions. Alaska residents, resource professionals and land managers need to "keep a sharp eye" out for potential introduced pests and quickly contact ACE, APHIS, or the Division of Agriculture. If introduced pests are quickly identified, the probability of successful eradication is increased.

Sitka Spruce Weevil

Pissodes strobi Peck

Adult Sitka spruce weevils were collected for the first time in the Anchorage Bowl in 1995 and again in 1996-97. The weevils were collected from infested nursery stock (blue spruce) brought into the state from the Pacific Northwest. Developing larvae, pupae, and callow adults were encountered in 1998 in out-plantings of spruce in west Anchorage; an indication that the spruce weevil may have adequate developmental conditions to become established in south-central Alaska. A follow-up ground check in the west Anchorage area found no new Sitka spruce weevil activity on new out-plantings. All of the infested shoots seen in this area were clipped and disposed of. In 1999, Sitka spruce weevils were found in a State of Alaska, Department of Transportation landscape planting near Tudor Road and "C" St. in Anchorage. The infested terminals were clipped and destroyed. In the spring of 2000, the Sitka spruce weevil was found to cause the death of dozens of Colorado spruce terminal leaders in nursery stock. The Anchorage nursery had imported the trees from Oregon in the fall of 1999, stored them on a large lot, and the damage was apparent the following April. The affected leaders were removed and destroyed. We will continue to monitor the potential establishment of this serious pest of ornamental and native spruce.

Figure 11. An adult spruce weevil.

European Black Slug: Limacidae

Arion ater

Arion ater, the European black slug, was detected twice in a local Anchorage garden in 2000 and was likely imported on flats of bedding plants that originated from Washington State. A distinctive feature of this slug is the many grooves and ridges along the back. This reddish-brown slug has a distinctive striped red-orange skirt. When fully extended, this slug measures almost 6 inches in length. The European black slug is established in the northwest U.S. and is a serious pest of crops including corn, wheat, potatoes, beans and strawberries.

Bird Vetch

Vicca cracca L.

Do not be deceived by the pretty blueish-purple flowers. This climbing legume has been spotted growing aggressively around south Anchorage for the past several seasons, most notably along the Seward Highway. It is weak-stemmed with compound leaves and has a climbing habit that allows it to grow on and over other plants. It has been observed invading yards, other roadside locations, and along the Turnagain Arm trail in Chugach State Park. *Vicca cracca* is recognized as a restricted noxious weed by the State of Alaska. The easiest method to control this plant is by pulling it wherever encountered and bagging it up for disposal to ensure seeds are not left on site.

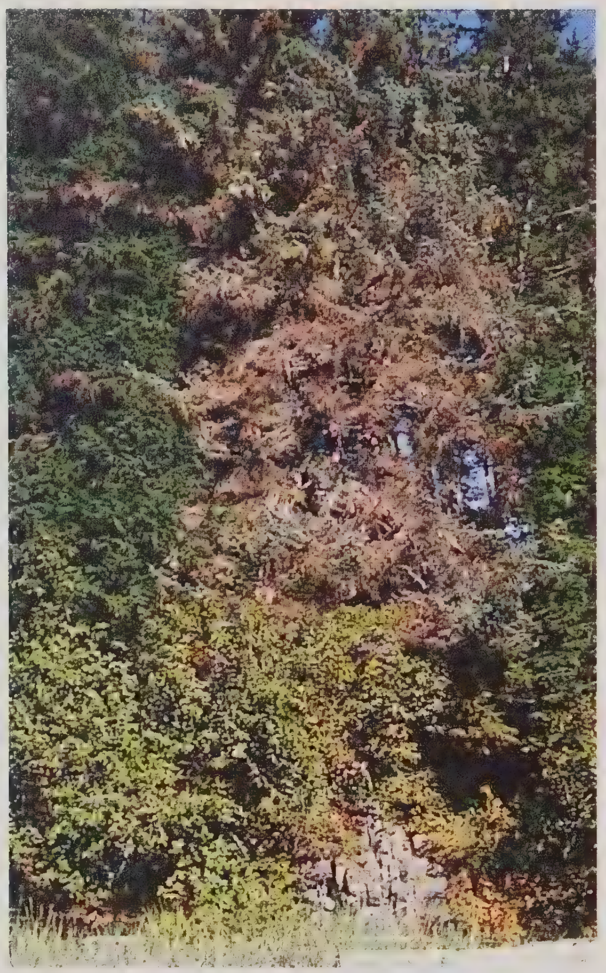
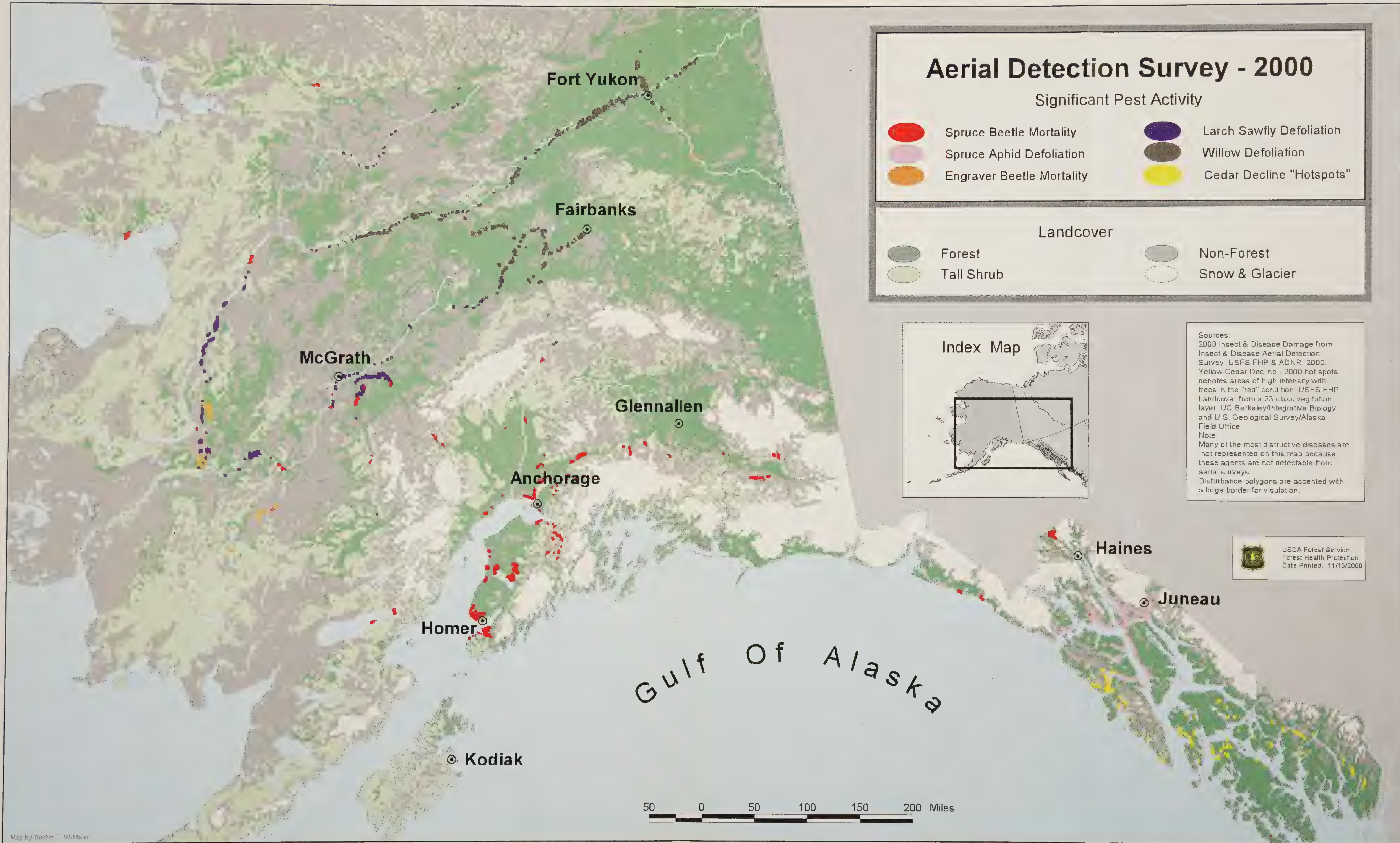


Figure 12. Spruce aphid damage can be seen in this Sitka spruce. Aphid killed needles are turning brown leaving only current year needles.

Figure 13. Hillsides can appear reddish orange with an active spruce beetle infestation.

Figure 14. Spruce beetle can help determine the dominant species of a given stand. This spruce beetle infestation will further favor the hardwood component in this stand.

Figure 15. Alder leaf blotch miner.



Aerial Detection Survey - 2000
Significant Pest Activity
Spruce Beetle Mortality
Spruce Aphid Defoliation
Engraver Beetle Mortality
Larch Sawfly Defoliation
Willow Defoliation
Cedar Decline "Hotspots"
Landcover
Forest
Tall Shrub
Non-Forest
Snow & Glacier
Index Map
Sources:
2000 Insect & Disease Damage from Insect & Disease Aerial Detection Survey, USFS FHP & ADNR, 2000.
Yellow-Cedar Decline - 2000 hot spots, denotes areas of high intensity with trees in the "red" condition, USFS FHP.
Landcover from a 23 class vegitation layer, UC Berkeley/Integrative Biology and U.S. Geological Survey/Alaska Field Office.
Note:
Many of the most distructive diseases are not represented on this map because these agents are not detectable from aerial surveys.
Disturbance polygons are accented with a large border for visulation.
USDA Forest Service
Forest Health Protection
Date Printed: 11/15/2000
Fort Yukon
Fairbanks
McGrath
Glennallen
Anchorage
Homer
Kodiak
Haines
Juneau
Gulf Of Alaska
50 0 50 100 150 200 Miles
Map by Dustin T. Wittwer

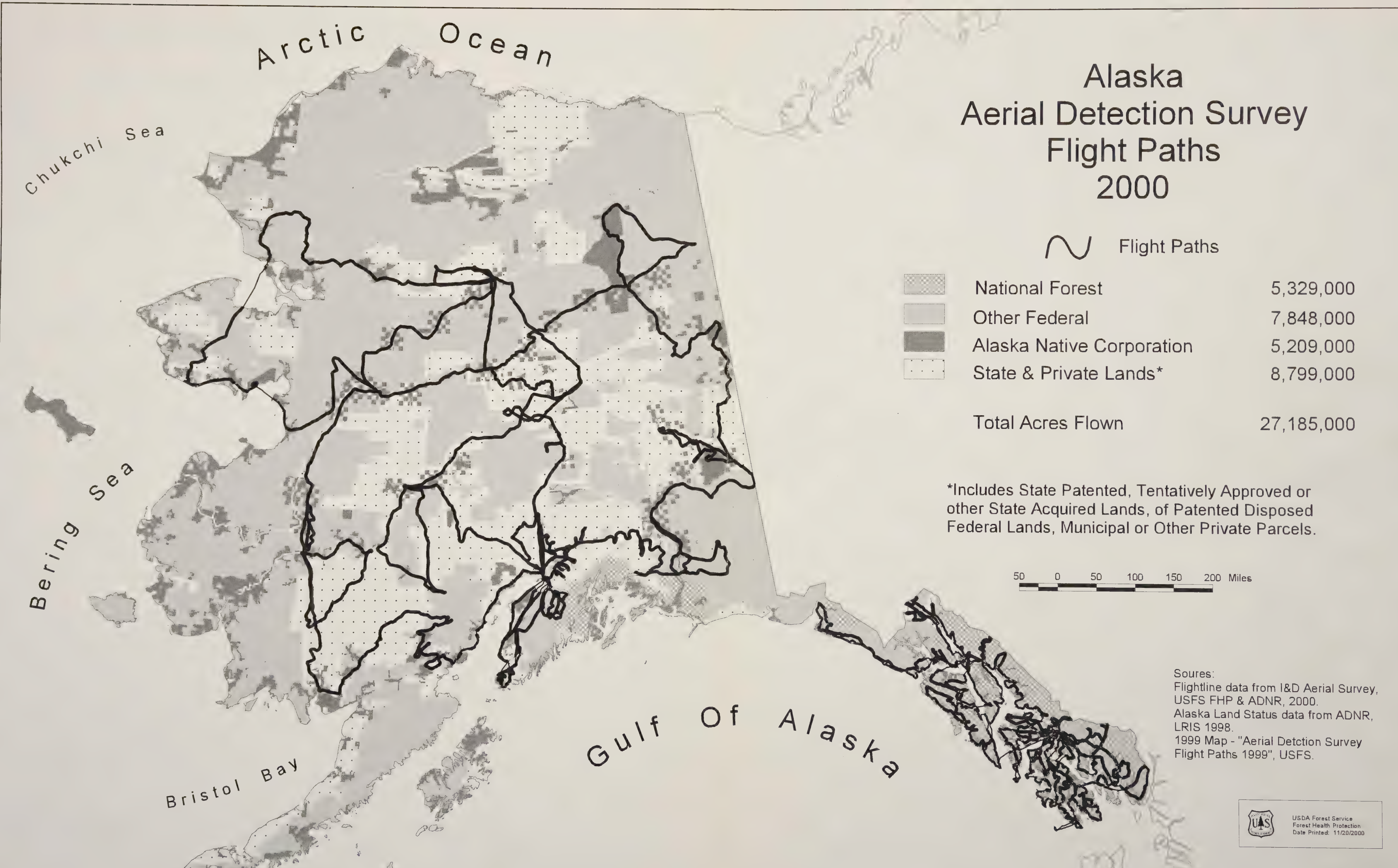

Alaska
Aerial Detection Survey
Flight Paths
2000
Flight Paths
National Forest 5,329,000
Other Federal 7,848,000
Alaska Native Corporation 5,209,000
State & Private Lands* 8,799,000
Total Acres Flown 27,185,000
*Includes State Patented, Tentatively Approved or other State Acquired Lands, of Patented Disposed Federal Lands, Municipal or Other Private Parcels.
50 0 50 100 150 200 Miles
Arctic Ocean
Chukchi Sea
Bering Sea
Bristol Bay
Gulf Of Alaska
Soures:
Flightline data from I&D Aerial Survey, USFS FHP & ADNR, 2000.
Alaska Land Status data from ADNR, LRIS 1998.
1999 Map - "Aerial Detction Survey Flight Paths 1999", USFS.
USDA Forest Service
Forest Health Protection
Date Printed: 11/20/2000

Figure 16. Spruce needle rust was found at high levels in 2000 throughout southeast AK.

Figure 17. These ancient dead yellow-cedar trees retain high quality wood many years after death.

Figure 18. Stem decay of paper birch caused by ***Phellinus igniarius****.*

Figure 19. Leathery annual fruiting bodies of ***Inonotus tomentosus****.*

STATUS OF DISEASES

ECOLOGICAL ROLES OF FOREST DISEASES

The economic impacts of forest diseases in Alaska have been recognized for some time. In southeast Alaska, heart rot fungi cause substantial cull of nearly 1/3 of the gross volume in old-growth hemlock-spruce forests. In the south-central and interior regions, substantial cull from decay fungi also occurs in white spruce, paper birch, and aspen forests. Traditionally, management goals sought to eliminate or reduce disease to minimal levels in an effort to maximize timber outputs. As forest management goals broaden to include enhancement of multiple resources and retaining structural and biological diversity, forest disease management can be assessed from an ecological perspective.

Figure 20. Decay fungi play vital roles in recycling nutrients and producing habitat.

We are learning that diseases are key ecological factors in Alaskan ecosystems. They enhance biological diversity, provide wildlife habitat, and alter forest structure, composition, and succession. As agents of disturbance in the western hemlock/Sitka spruce forests of southeast Alaska, diseases apparently contribute to the "breaking up" of even-aged stands as they are in transition (i.e., 150 to 200 years old) to old-growth phase. Diseases appear to be among the primary factors that maintain stability in the old-growth phase through small-scale (canopy-gap) level disturbance. Less is known about the ecological role of diseases in south-central and interior forests, however diseases appear to be agents of small-scale disturbance altering ecological processes in spruce and hardwood forests.

Forest practices can be used to alter the incidence of diseases to meet management objectives. Two of the principal types of conifer disease that influence forest structure in Alaska, heart rot and dwarf mistletoe, can apparently be managed to predictable levels. If reducing disease to minimal levels is a management objective, then both heart rot and mistletoe can be largely eliminated through clearcut harvesting and even-aged management. However, to reduce disease to minimal levels in all instances is to diminish the various desirable characteristics of forest structure and ecosystem functions that they influence. Heart rot organisms and dwarf mistletoe provide unique forest structural components that may be lost for decades or perhaps centuries after clearcutting. Research indicates that harvesting practices other than clearcutting can be used to retain structural and biological diversity by manipulating these diseases to desired levels. Since heart rot in coastal stands is associated with natural bole scars and top breakage, levels of heart rot can be manipulated by controlling the incidence of bole wounding and top breakage during stand entries for timber removal. Levels of dwarf mistletoe can be manipulated through the distribution, size, and infection levels of residual trees that remain after harvest. Our ongoing research indicates that the incidence and effects of these diseases will vary through time in a predictable manner by whatever silvicultural strategy is used.

Research is currently underway in south-central and interior Alaska to assess the economic and ecological impacts of root diseases. Root diseases are difficult to detect, remain active on site in trees and stumps for decades, infect multiple age classes, and cause substantial volume loss. Ecologically, root diseases create canopy gaps that contribute to biodiversity, provide wildlife habitat, and alter successional processes. Elimination of root rot from an infected site is challenging because the diseased material is primarily located in buried root systems. Establishment of non-host material within root rot centers is an effective option for manipulating levels of root disease. Ongoing research on the relationship between species composition and root disease incidence in south-central and interior Alaska will provide important information to forest managers for both ecological and economic considerations for disease management.

Table 5. Suspected effects of common diseases on ecology in Alaskan forests.

Effects by each disease of disorder are qualified as: - = negligible or minor effect, + = some effect, ++ = dominant effect.

ECOLOGICAL FUNCTION ALTERED

DISEASE	STRUCTURE	COMPOSITION	SUCCESSION	WILDLIFE HABITAT
STEM DISEASES				
Dwarf mistletoe	++	+	+	++
Hemlock cankers	-	+	-	+
Hardwood cankers	+	+	+	-
Spruce broom rust	+	-	-	++
Hemlock bole fluting	-	-	-	+
Western gall rust	-	-	-	-
HEART ROTS				
(Many species)	++	+	++	++
ROOT DISEASES				
(several species)	+	++	++	+
FOLIAR DISEASES				
Spruce needle rust	-	-	-	-
Spruce needle blights	-	-	-	-
Hemlock needle rust	-	-	-	-
Cedar foliar diseases	-	-	-	-
Hardwood leaf diseases	-	-	-	-
SHOOT DISEASES				
Sirococcus shoot blight	-	-	-	-
Shoot blight of yellow-cedar	-	+	-	-
DECLINES				
Yellow-cedar decline	++	++	++	+
ANIMAL DAMAGE				
Porcupines	+	-	-	+
Brown Bears	+	-	-	+
Moose	+	+	-	+

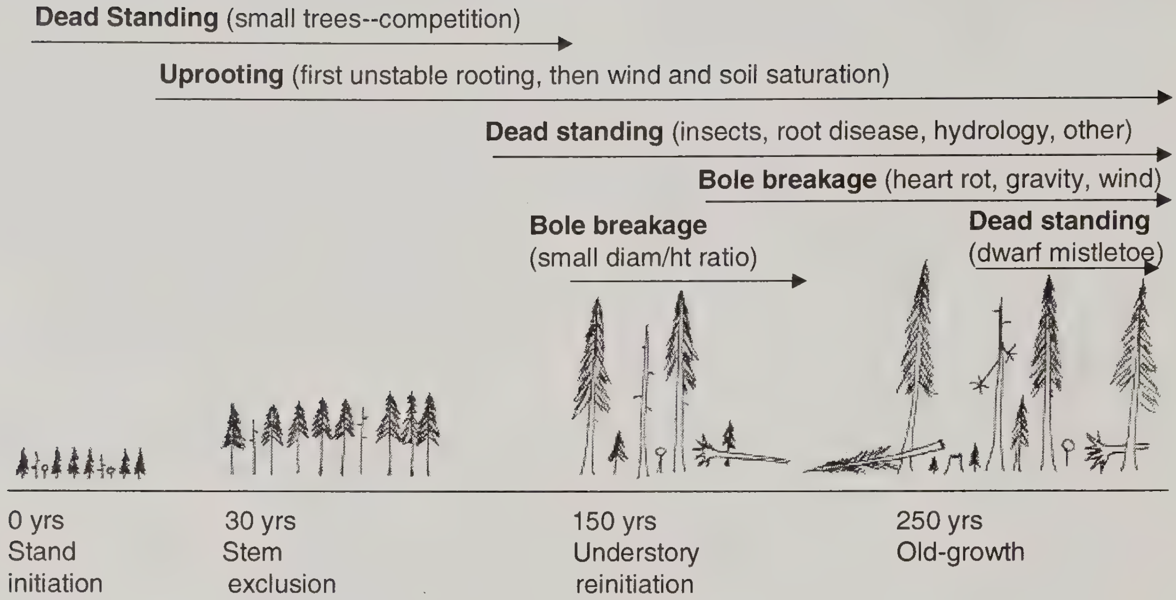


Figure 21. Stages of stand development and associated forms of tree mortality following catastrophic disturbance (e.g., clearcut or storm). Competition causes most mortality in young stands and trees usually die standing. Disease in the form of heart rot plays an active role in small-scale disturbance in the third, transitional stage and then is a constant factor in the maintenance of the old-growth stage. The time scale that corresponds to stages of stand development varies by site productivity. Many old-growth structures and conditions may be present by 250 years on some sites in Southeast Alaska. The old-growth stage may persist for very long periods of time in protected landscape positions.

STEM DISEASES

Hemlock Dwarf Mistletoe

Arceuthobium tsugense (Rosendhal) G.N. Jones

Hemlock dwarf mistletoe is an important disease of western hemlock in unmanaged, old-growth stands throughout southeast Alaska as far north as Haines(M5, M6) *. Although the range of western hemlock extends to the northwest along the Gulf of Alaska, dwarf mistletoe is absent from Cross Sound to Prince William Sound. The incidence of dwarf mistletoe in Southeast Alaska varies in old-growth hemlock stands in southeast Alaska from stands in which every mature western hemlock is severely infected to other stands in which the parasite is absent. The dominant small-scale (canopy gap) disturbance pattern in the old forests of coastal Alaska favors the short-range dispersal mechanism of hemlock dwarf mistletoe and may explain the common occurrence of the disease here. Infection of Sitka spruce is uncommon and infection of mountain hemlock is rare. The disease is uncommon on any host above elevations of approximately 1,000 feet. Heavily infected western hemlock trees have branch proliferations (witches' brooms), bole deformities, reduced height and radial growth, less desirable wood characteristics, greater likelihood of heart rot, top-kill, and severely infected trees may die. We have found the aggressive heart rot fungus, *Phellinus hartigii,* associated with large mistletoe brooms on western hemlock.

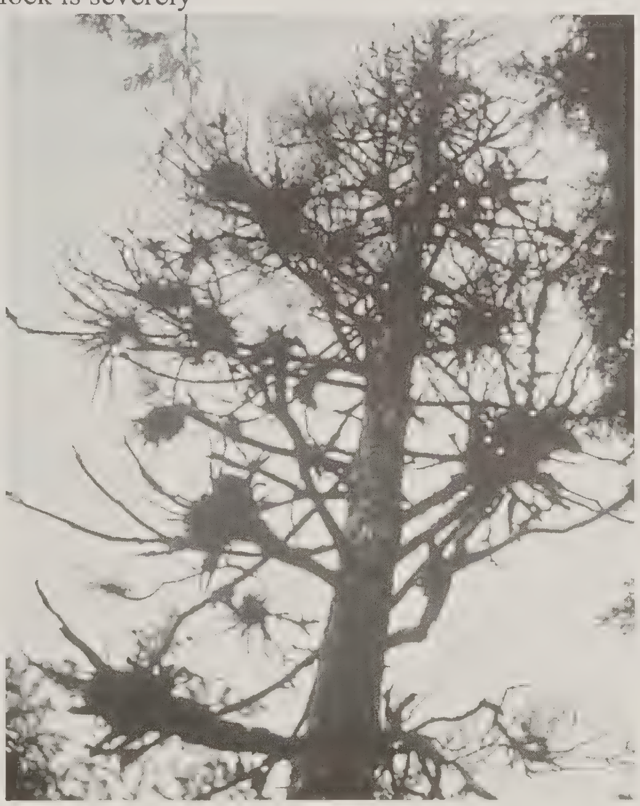


Figure 22. Large brooms are the most visible characteristic of hemlock dwarf mistletoe.

These symptoms are all potential problems in stands managed for wood production. Growth loss in heavily infested stands can reach 40% or more. On the other hand, witches' brooms, wood decay associated with bole infections, and scattered tree mortality can result in greater diversity of forest structure and increased animal habitat. Witches' brooms may provide hiding or nesting habitats for birds or small mammals, although this topic has not been adequately researched in Alaska. The inner bark of swellings and the seeds and shoots of the parasitic plants are nutritious and often consumed by small mammals (e.g., most likely flying squirrels). However, heavily infected hemlock stands can begin to decline and collapse to the extent that vertical structural diversity and animal habitat are diminished. Stand composition is altered when mixed-species stands are heavily infected; growth of resistant species such as Sitka spruce and cedar is enhanced.

Spread of the parasite into young-growth stands that regenerate following "clear cutting" is typically by: 1) infected non-merchantable hemlock trees (residuals) which are sometimes left standing in cut-over areas, 2) infected old-growth hemlocks on the perimeter of cut-over areas, and 3) infected advanced reproduction. Residual trees may play the most important role in the initial spread and long-term mistletoe development in young stands. Managers using alternative harvest techniques (e.g., large residuals left standing in clearcuts, small harvest units, or partial harvests) should recognize the potential reduction in timber volume and value from hemlock dwarf mistletoe under some of these silvicultural scenarios. But substantial reductions to timber are only associated with very high disease levels. High levels of hemlock dwarf mistletoe will only result if numerous, large, intensely-infected hemlocks are well-distributed after harvest. Mistletoe management appears to be a good tool in balancing several resource objectives. Selective harvesting techniques will be the silvicultural method for maintaining desirable levels of this disease if management intends to emphasize structural and biological diversity along with timber production.

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* The number following place names refer to ecosystem section designations. Refer to page 7 and Appendix D.

Hemlock Canker
Unidentified fungus and road dust

Hemlock canker disease subsided over last year's levels. In past outbreaks, it has been common along unpaved roads on Prince of Wales Island, Kuiu Island (Rowan Bay road system), Chichagof Island (Corner Bay road system) and near Carroll Inlet on Revillagigedo Island (M4). It was also observed in several roadless areas.

The causal agent has not been conclusively determined. Road dust and a fungus appear to be responsible for outbreaks of this disease. Ecologically, modification of stand composition and structure are the primary effects of hemlock canker. Tree species, other than western and mountain hemlock, are resistant and benefit from reduced competition. Wildlife habitat, particularly for deer, may be enhanced where the disease kills understory hemlock which tends to out-compete the more desirable browse vegetation.

Spruce Broom Rust
Chrysomyxa arctostaphyli Diet.

Broom rust is common on spruce throughout interior and south-central Alaska but is found in only several local areas of southeast Alaska (e.g., Halleck Harbor area of Kuiu Island and Glacier Bay (M4)). The disease is abundant only where spruce grow near the alternate host, bearberry or kinnikinnick (*Arctostaphylus uva-ursi*) in Alaska. The fungus cannot complete its life cycle unless both host types (spruce and bearberry) are present.

Infections by the rust fungus result in dense clusters of branches or witches' brooms on white, Lutz, Sitka, and black spruce. The actual infection process may be favored during specific years, but the incidence of the perennial brooms changes little from year to year. The disease may cause slowed growth of spruce, although this has not been determined by research. Witches' brooms may serve as entrance courts for heart rot fungi, including *Phellinus pini*.

Ecologically, the dense brooms provide important nesting and hiding habitat for birds and small mammals. In interior Alaska, research on northern flying squirrels suggests that brooms in white spruce are an important habitat feature for communal hibernation and survival in the coldest periods of winter.

Western Gall Rust
Peridermium harknessii J.P. Moore

Infection by the gall rust fungus *P. harknessii* causes spherical galls on branches and main boles of shore pine. The disease was common throughout the distribution of pine in Alaska in 2000 (M2, M4, M6). Infected pine tissues are swollen but not always killed by the rust fungus. Another fungus, *Nectria macrospora*, colonized and killed many of the pine branches with *P. harknessii* galls this year. The combination of the rust fungus and *N. macrospora* frequently caused top-kill. The disease, although abundant, does not appear to have a major ecological effect in Alaskan forests.

HEART ROTS OF CONIFERS

Heart rot decay causes enormous loss of wood volume in Alaskan forests. Approximately 1/3 of the old-growth timber volume in southeast Alaska is defective largely due to heart rot fungi. These extraordinary effects occur where long-lived tree species predominate, such as old-growth forests in southeast Alaska. The great longevity of individual trees allows ample time for the slow-growing decay fungi to cause significant amounts of decay. Wood decay fungi play an important role in the structure and function of coastal old-growth forests where fire and other forms of catastrophic disturbance are uncommon. By predisposing large old trees to bole breakage, these fungi serve as important disturbance factors that cause small-scale canopy gaps. All major tree species in southeast Alaska are susceptible to heart rot decay and bole breakage.

In south-central and interior Alaska, heart rot fungi cause considerable volume loss in mature white spruce forests. Most heart rot fungi apparently enter trees through dead or broken branches, frost cracks, or bole wounds. In the boreal forests, large-scale disturbance agents, including wildfire, insect outbreaks (e.g., spruce beetle), and flooding, are key factors influencing forest structure and composition. The importance of small-scale disturbances caused by decay fungi is not known.

Figure 23. ***Fomitopsis pinicola*** *is an important heartrot fungus in live trees but also the dominant decomposer of dead conifer trees.*

Heart rot fungi enhance wildlife habitat -- indirectly by increasing forest diversity through gap formation and more directly by creating hollows in live trees or logs for species such as bears and cavity nesting birds. Wood decay in both live and dead trees are centers of biological activity, especially for small organisms. Wood decay is the initial step in nutrient cycling of wood substrates, has associated bacteria that fix nitrogen, and contributes large masses of stable structures (e.g., partially modified lignin) to the humus layer of soils.

The importance of decay fungi in managed young-growth conifer stands is less certain. Wounds on live trees caused by logging activities allow for the potential of decay fungi to cause appreciable losses. Heart rot in managed stands can be manipulated to desirable levels by varying levels of bole wounding and top breakage during stand entries. In some instances, bole breakage is sought to occur in a specific direction (e.g., across streams for coarse woody debris input). Artificially wounding trees on the side of the bole that faces the stream can increase the likelihood of tree fall in that direction. In southeast Alaska, we investigated how frequently fungi enter wounds of different sizes and the rate of subsequent decay in these wounded trees. Generally, larger, deeper wounds and larger diameter breaks in tops result in a faster rate of decay. Results indicate that heart rot development is much slower in southeast Alaska than areas studied in the Pacific Northwest.

Table 6. Common wood decay organisms of live trees in Alaska

	TREE SPECIES INFECTED				
Heart and butt rot fungi*	Western hemlock	Sitka spruce	Western red cedar	White/Lutz spruce	Mountain hemlock
Laetiporus sulphureus	X	X		X	X
Phaeolus schweinitzii	X	X		X	
Fomitopsis pinicola	X	X		X	X
Phellinus hartigii	X				
Phellinus pini	X	X		X	X
Ganoderma spp.	X	X		X	
Coniophora spp.				X	X
Armillaria spp.	X	X	X	X	X
Inonotus tomentosus				X	
Heterobasidion annosum	X	X			
Ceriporiopsis rivulosa			X		
Phellinus weirii			X		
Echinodontium tinctorium					X

* Some root rot fungi were included in this table because they are capable of causing both root and butt rot of conifers.

Wood decay fungi decompose branches, roots, and boles of dead trees; therefore, they play an essential role in recycling wood in forests. However, sap rot decay also routinely and quickly develops in spruce trees attacked by spruce beetles. Large amounts of potentially recoverable timber volume are lost annually due to sap rot fungi on the Kenai Peninsula. Significant volume loss from sap rot fungi typically occurs several years after tree death. The most common sap rot fungus associated with spruce beetle-caused mortality is *Fomitopsis pinicola*, the red belt fungus.

STEM DECAY OF HARDWOODS

Stem decay is the most important cause of volume loss and reduced wood quality in Alaskan hardwood species. In south-central and interior Alaska, incidence of stem decay fungi increases as stands age and is generally high in stands over 100 years old. The most reliable decay indicator is the presence of fruiting bodies (mushrooms or conks) on the stem. Other external indicators of decay include frost cracks, broken tops, dead branch stubs, and trunk wounds. Stem decay fungi will limit harvest rotation age of forests that are managed for wood production purposes. Studies are currently underway in paper birch forests to identify the most important stem decay fungi and assess the relationships among decay incidence, stand age, and presence of decay indicators.

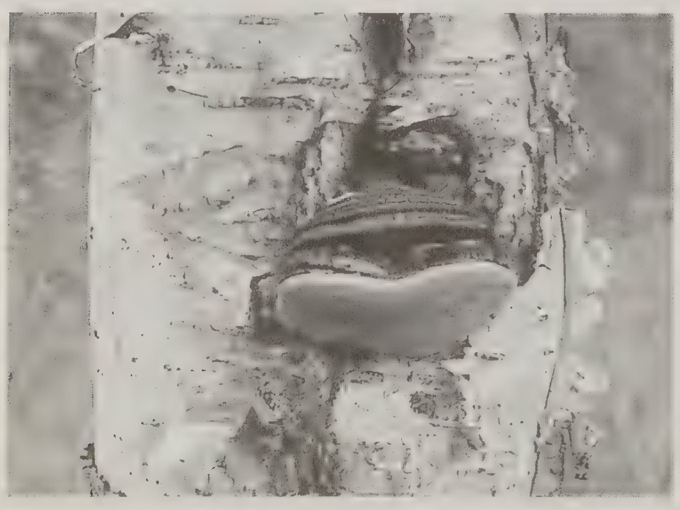

Figure 24. ***Phellinus igniarius*** *conk on paper birch.*

Ecologically, stem decay fungi alter stand structure and composition and appear to be important factors in the transition of even-aged hardwood forests to mixed species forests. Bole breakage of hardwoods creates canopy openings, allowing release of understory conifers. Trees with stem decay, broken tops, and collapsed stems are preferentially selected by wildlife for cavity excavation. Several mammals, including the northern flying squirrel, are known to use tree cavities year-round for nest and cache sites.

In south-central and interior Alaska, the following fungi are the primary cause of wood decay in live trees:

Paper birch
Phellinus igniarius
Inonotus obliquus
Pholiota spp.
Armillaria spp.

Trembling aspen
Phellinus tremulae
Pholiota spp.
Ganoderma applanatum
Armillaria spp.

A number of fungi cause stem decay in balsam poplar, black cottonwood, and other hardwood species in Alaska.

SHOOT BLIGHTS and CANKERS

Sirococcus Shoot Blight

Sirococcus strobilinus Pruess.

The shoots of young-growth western hemlocks were killed in moderate levels by the blight fungus *S. strobilinus* in southeast Alaska during 2000. Sitka spruce and mountain hemlock were attacked, but less frequently and less severely. Thinning may be of some value in reducing damage by the fungus as thinned stands have fewer infections than unthinned stands.

This disease is typically of minimal ecological consequence because infected trees are not often killed and young hemlock stands are so densely stocked. Species composition may be altered to some degree where trees other than western hemlock may be favored by the disease.

Shoot Blight of Yellow-cedar
Apostrasseria sp.

Yellow-cedar regeneration suffered infection and shoot blight by the fungus *Apostrasseria* sp. in southeast Alaska in 2000 as it does every year. The disease, however, does not affect mature cedar trees. Attack by the fungus causes terminal and lateral shoots to be killed back 10 to 20 cm on seedlings and saplings during winter or early spring. Entire seedlings up to 0.5m tall are sometimes killed. The newly discovered fungus that causes the disease, *Apostrasseria* sp., is closely related to other fungi that cause disease on plants under snow. Frost or insect feeding can sometimes be confused with this shoot blight disease. The fungus *Herpotrichia juniperi* is often found as a secondary invader on seedling tissues that die from any of these causes.

This shoot blight disease probably has more ecological impact than similar diseases on other host species because the natural regeneration of yellow-cedar is limited in many areas. By killing the leaders of yellow-cedar seedlings and diminishing their ability to compete with other vegetation, the pathogen reduces the regeneration success of yellow-cedar and thereby alters species composition.

Canker Fungi
Cryptosphaeria populina (Pers.) Sacc.
Cenangium singulare (Rehm.) D. & Cash
Ceratocystis fimbriata Ell. & Halst.
Cytospora chrysosperma Pers. ex Fr.
Nectria galligena Bres.

These fungi primarily cause trunk deforming cankers and wood decay of many hardwood species, particularly trembling aspen, in south-central and interior Alaska. Although most are considered weak parasites, *C. singulare* can girdle and kill a tree in three to ten years. All the canker-causing fungi were at endemic levels in 2000. Ecologically, canker fungi alter stand structure, composition, and successional patterns through trunk deformity and bole breakage.

FOLIAR DISEASES

Spruce Needle Rust
Chrysomyxa ledicola Lagerh.
Chrysomyxa weirii Jacks.

Spruce needle rust, caused by *C. ledicola*, occurred at endemic levels across the state except in southeast Alaska where the disease was found at very high levels for the second year in a row.

The disease was epidemic in southeast Alaska in wet, boggy areas wherever spruce and Labrador-tea coexisted. Up to 100% of current-year's spruce needles were infected in many of these areas. With missing needles from last year's outbreak, these trees now have a rather thin appearance. Buds were not infected, however, and even with such high disease levels, most trees should recover.

The spores that infect spruce needles are produced on the alternate host, Labrador-tea (*Ledum spp.*), a plant that is common in boggy areas; thus the disease on spruce is most pronounced in these boggy (muskeg) areas. Although the disease can give spruce trees the appearance of being nearly dead, trees rarely die of this disease even in years of intense infection.

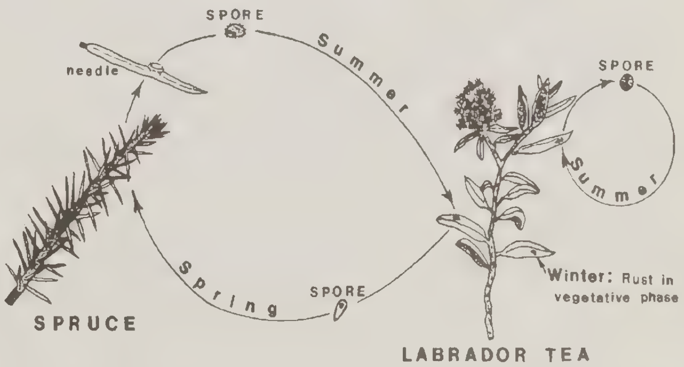

Figure 25. The life cycle involves two host plants: spruce and Labrador tea.

On Sitka spruce, the primary ecological consequence of the disease may be to reduce tree vigor of a species already poorly adapted to boggy sites. Repeated infection of spruce may alter forest composition by favoring other tree species.

The foliar rust fungus *C. weirii* was found sporulating on one-year-old Sitka spruce needles in several areas of southeast Alaska during spring. Unlike most other rust fungi, no alternate host is necessary to complete its life cycle. Little ecological or economic impact results from this disease.

*Figure 26. The yellow fruiting bodies of **Chrysomyxa ledicola** can be seen on the current year needles of this spruce.*

Spruce Needle Blights

Lirula macrospora (Hartig) Darker
Lophodermium picea (Fuckel) Höhn.
Rhizosphaera pini (Corda) Maubl.

The fungus *L. macrospora* is the most important needle pathogen of spruce. In 2000 it occurred at low levels in most areas within the range of Sitka and white spruce. Throughout southeast Alaska, the disease was most common on young Sitka spruce and the lower crowns of larger trees. *L. picea* was present at low infection levels in 2000. This disease is more typical of larger, older trees of all spruce species in Alaska. *R. pini* continued at endemic levels after causing damage several years ago in coastal Alaska. Damage closely resembles that caused by spruce needle aphid. Microscopic observation of the tiny fruiting bodies on infected needles is necessary for proper identification.

The primary impact of these needle diseases is generally one of appearance. They can cause severe discoloration or thinning of crowns but typically have only negligible ecological consequence. However, repeated heavy infections may slow the growth of spruce and benefit neighboring trees, thereby altering species composition to some degree.

Hemlock Needle Rust

Pucciniastrum vaccinii (Rab.) Joerst.

Hemlock needle rust was found at low endemic levels in 2000 after a high incidence several years ago. In 1996, the disease was most damaging near Yakutat (M5) where it caused defoliation of western hemlock, especially on trees growing adjacent to harvested sites. Elsewhere, infected needles were found, but hemlock trees were not heavily defoliated. The alternate hosts for the rust fungus include several blueberry species (*Vaccinium*). Infection levels usually return to endemic levels in a year or so and the disease is not expected to have major ecological change.

Willow Rust

Melampsora epitea Thuem.

Willow rust, caused by one or more races of *M. epitea*, occurred at endemic levels in the interior in 2000, after a high incidence several years ago. The rust fungus causes a yellow leaf spot or blight on willow leaves. No alternative host is needed to complete its life cycle. The fungus overwinters on willow leaves or buds, readily infecting willows in successive years. Repeated rust infection of leaves may reduce host vigor.

Foliage Diseases of Cedars

Gymnosporangium nootkatense Arth.
Didymascella thujina (Durand) Maire

Two fungi that infect the foliage of cedar, *G. nootkatense* on yellow-cedar and *D. thujina* on western redcedar, occurred at endemic levels this year. *G. nootkatense* was found at the very northwest limits of the natural range of yellow-cedar in Prince William Sound. *D. thujina* was the more damaging of the two fungi and was common wherever its host was found. Neither fungus resulted in severe defoliation or death of cedar trees. Neither disease has major ecological effects.

ROOT DISEASES

Three important tree root diseases occur in Alaska: tomentosus root rot, annosus root disease, and armillaria root disease. The laminated root disease caused by a form of the fungus *Phellinus weirii*, so important in some western forests of British Columbia, Washington, and Oregon, is not present in Alaska. A non-root disease form of the fungus is present in southeast Alaska, where it causes a white rot in western redcedar, contributing to the very high defect levels in this tree species.

Although relatively common in Alaskan forests, root diseases are often mis-diagnosed or overlooked. Diagnosing root disease can be challenging because the infected tissue is primarily below ground in roots and infected trees may lack above-ground symptoms. Identification of a root disease should not be made solely on the basis of crown symptoms. Above ground symptoms, such as chlorotic foliage, stress cone crop, and reduced branch growth can be caused by a wide array of stress factors other than root diseases.

Root disease pathogens affect groups of trees in progressively expanding disease centers. Typically, disease pockets contain dead trees in the center and living, but infected trees in various stages of decline, at the edges. Root disease fungi spread most efficiently from tree to tree through root contacts. Infected trees are prone to uprooting, bole breakage, and outright mortality due to the extensive decay of root systems and the lower tree bole. Volume loss attributed to root diseases can be substantial, up 1/3 of the gross volume. In managed stands, root rot fungi are considered long-term site problems because they can remain alive and active in large roots and stumps for decades, impacting the growth and survival of susceptible host species on infected sites.

Ecologically, root diseases are considered natural, perhaps essential, parts of the forest altering stand structure, composition, and increasing plant community diversity through canopy openings and scattered mortality. Resistant tree species benefit from reduced competition within infection centers. Wildlife habitat may be enhanced by small-scale mortality centers and increased volume of large woody downed material.

Armillaria Root Disease

Armillaria **spp.**

Several species of *Armillaria* occur in the coastal forests of southeast Alaska, but in general, these species are less-aggressive, saprophytic decomposers that only kill trees when they are under some form of stress. Studies in young, managed stands indicate that *Armillaria* spp. can colonize stumps, but will not successfully attack adjacent trees.

Figure 27. Mushrooms of ***Armillaria sinapina.***

Several species of *Armillaria* occur in south-central and interior Alaska, some attack conifers while others attack hardwoods. Most species appear to be weak pathogens invading trees under some form of stress. Research is currently underway to determine the species present and their impacts in the boreal forests.

Tomentosus Root Disease

Inonotus tomentosus (Fr.) Teng.

I. tomentosus causes root and butt-rot of white, Lutz, Sitka, and black spruce. The fungus may also attack lodgepole pine and tamarack. Hardwood trees are not considered hosts. The disease appears to be widespread across the native range of spruce in south-central and interior Alaska, but to date, has not been found in southeast Alaska.

Spruce trees of all ages are susceptible to infection through contact with infected roots. Infected trees exhibit growth reduction or mortality, depending on age. Younger trees may be killed outright while older trees may persist in a deteriorating condition for many years. Volume loss in the butt log of older infected trees can be substantial, up 1/3 of the gross volume. Trees with extensive root and butt decay are prone to

uprooting and bole breakage. Individual mortality centers (groups of infected trees) are typically small, however, coalescing centers can occupy large areas.

Studies in cut-over stands indicate that *I. tomentosus* will remain alive in colonized stumps for at least three decades, and successfully attack adjacent trees through root contacts. Thus, spruce seedlings planted in close proximity of infected stumps are highly susceptible to infection through contacts with infected roots. Recognition of this root disease is particularly important in managed stands where natural regeneration of white and Lutz spruce is limited and adequate restocking requires planting.

Tomentosus root disease can be managed in a variety of ways depending on management objectives. Options for manipulating levels of root disease on infested sites include: establishment of non-susceptible species in root rot centers (i.e., hardwood trees), avoid planting susceptible species within close proximity of diseased stumps, and removal of diseased stumps and root systems. Studies are currently underway to assess mortality in young growth stands and to determine site factors that influence disease incidence and severity.

Annosus Root & Butt Rot

Heterobasidion annosum (Fr.) Bref.

Annosus commonly causes root and butt-rot in old-growth western hemlock and Sitka spruce forests in southeast Alaska (M2, M4). To date, *H. annosum* has not been documented in south-central or interior Alaska.

Elsewhere in the world, spores of the fungus are known to readily infect fresh stump surfaces, such as those found in clearcuts or thinned stands. Studies in managed stands in southeast Alaska, however, indicate limited stump infection and survival of the fungus. Thus, this disease poses minimal threat to young managed stands from stump top infection.

Reasons for the limited stump infection may be related to climate. High rainfall and low temperatures, common in Alaska's coastal forests, apparently hinder infection by spores.

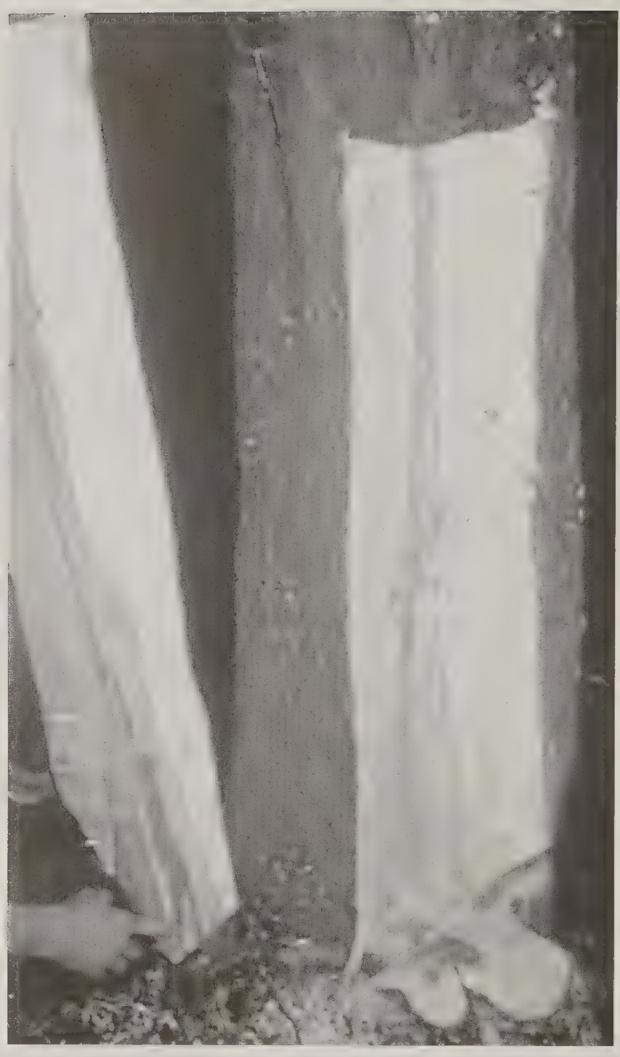

Figure 28. Annosus decay can be seen in the cutout near the base of this spruce tree.

DECLINES AND ABIOTIC FACTORS

Yellow-cedar Decline

Decline and mortality of yellow-cedar persists as one of the most spectacular forest problems in Alaska. Approximately 478,453 acres of decline have been mapped during aerial detection surveys. Concentrated mortality occurs in a wide band from western Chichagof and Baranof Islands to the Ketchikan area (M4).

All research suggests that contagious organisms are not the primary cause for this extensive mortality. Some site factor, probably associated with poorly-drained anaerobic soils, appears to be responsible for initiating and continuing cedar decline. Two hypotheses have been proposed to explain the primary cause of death in yellow-cedar decline:

- Toxins are produced by decomposition in the wet, organic soils, or
- Shallow fine roots are damaged from freezing, associated with climatic warming and reduced insulating snowpack in the last century.

These hypotheses are developed in some detail (Hennon and Shaw 1994, 1997). Interestingly, considerable concentrations of newly-killed trees were evident in declining forests during 1996 and 1997, perhaps a response to the unusually prolonged cold temperatures with little snowpack that persisted during the previous two winters. Whatever the primary cause of this mysterious decline, all available information indicates that it is probably a naturally-occurring phenomenon. We are now monitoring soil temperature and hydrology in one area to evaluate these ideas.

Figure 29. Dead yellow-cedar trees dominate some stands in southeast Alaska.

Research suggests that the total acreage of yellow-cedar decline has been increasing very gradually; the slow increase in area has been a result of the expansion of existing decline (<3 feet/year). Most stands contain trees that died up to 100 years ago (snags still standing), as well as recently killed cedars, dying cedars (with yellow, red, or thinning crowns), healthy cedars, and other tree species.

Ground surveys show that 65% of the basal area of yellow-cedar is dead on this acreage. Other tree species are affected in different ways: on some sites they produce increased growth, presumably due to less competition, and on other sites they experience slowed growth and mortality due to deteriorating site conditions (poor drainage). Species change to western hemlock and mountain hemlock and large increases in understory biomass accumulation for brushy species appear to be occurring in some stands where decline has been ongoing for up to a century.

The primary ecological effect of yellow-cedar decline is to alter stand structure (i.e., addition of numerous snags) and composition (i.e., yellow-cedar diminishing and other tree species becoming more numerous) that leads to eventual succession favoring other conifer species. The creation of numerous snags is probably not particularly beneficial to cavity-using animals because yellow-cedar wood is less susceptible to decay. Region-wide, this excessive mortality of yellow-cedar may lead to diminishing populations (but not extinction) of yellow-cedar, particularly when the poor regeneration of the species is considered.

The large acreage of dead yellow-cedar and the high value of its wood suggest opportunities for salvage. Cooperative studies with the Wrangell Ranger District, the Forest Products Laboratory in Madison, Wisconsin, Oregon State University, and State and Private Forestry are investigating the mill-recovery and wood properties of snags of yellow-cedar that have been dead for varying lengths of time. This work includes wood strength properties, durability (decay resistance), and heartwood chemistry.

Little is known about wildlife use and dependency on yellow-cedar forests. We would like to evaluate birds' use of each of the snag classes as nesting or feeding habitat. In a companion study that we have initiated, we are investigating the insect community on dead cedars; insects on recently killed trees may be an important prey source for insectivorous birds.

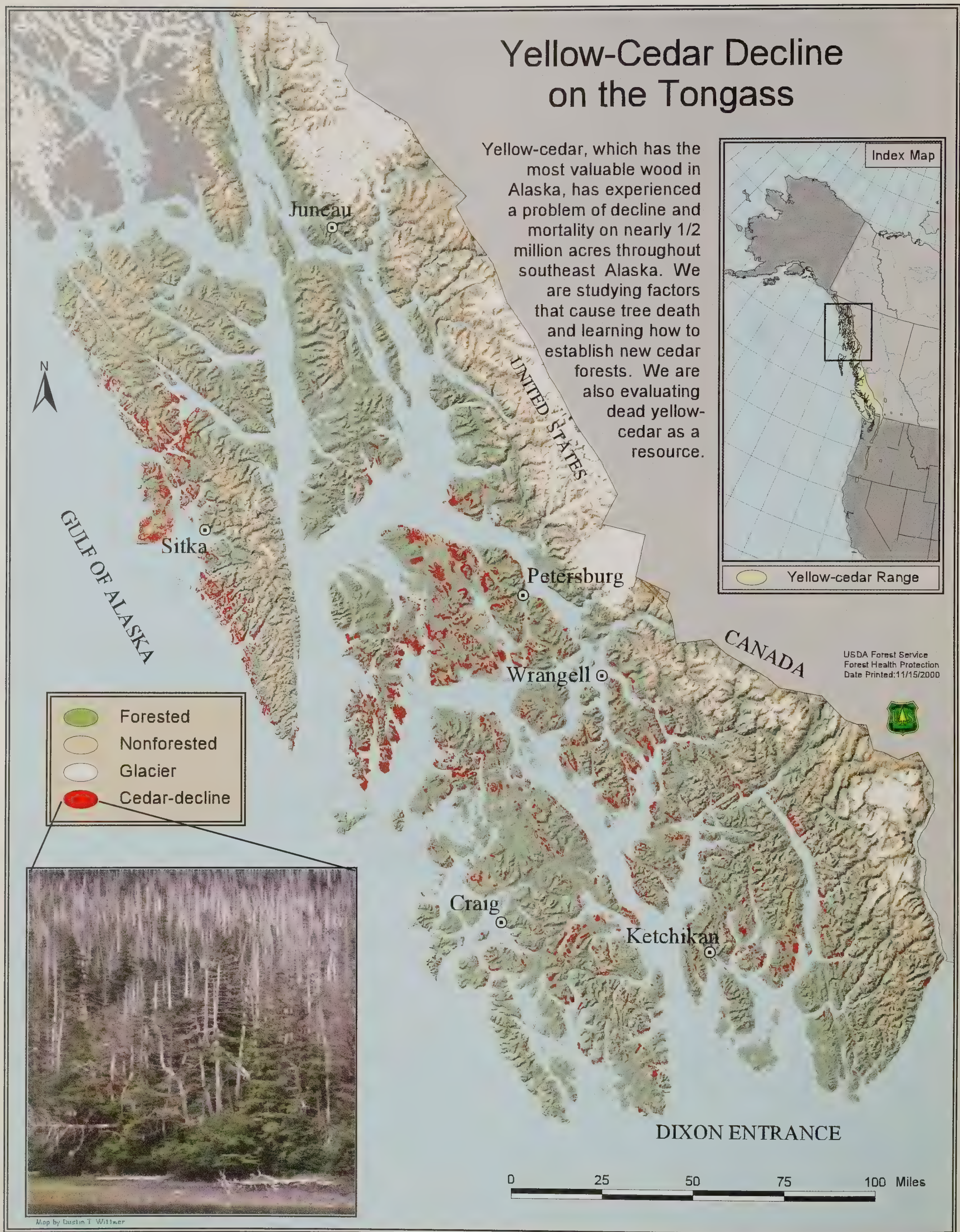
Yellow-Cedar Decline
on the Tongass
Yellow-cedar, which has the most valuable wood in Alaska, has experienced a problem of decline and mortality on nearly 1/2 million acres throughout southeast Alaska. We are studying factors that cause tree death and learning how to establish new cedar forests. We are also evaluating dead yellow-cedar as a resource.
Index Map
Yellow-cedar Range
Juneau
Sitka
Petersburg
Wrangell
Craig
Ketchikan
UNITED STATES
CANADA
GULF OF ALASKA
DIXON ENTRANCE
N
Forested
Nonforested
Glacier
Cedar-decline
USDA Forest Service
Forest Health Protection
Date Printed:11/15/2000
0
25
50
75
100 Miles
Map by Dustin T. Wittwer

Table 7. **Acreage affected by yellow-cedar decline in southeast Alaska in 2000 by ownership**

	Acres
NATIONAL FOREST LAND	***437,444***
Chatham Area Total	***116,724***
Juneau Ranger District	865
Hoonah Ranger District	977
Sitka Ranger District	
Chichagof I	33,802
Baranof I	48,754
Kruzof I	26,905
Sub-total	109,461
Admiralty Island Nat'l Mon. Wilderness	5,421
Stikine Area Total	***197,711***
Petersburg Ranger District	
Kupreanof I	72,786
Kuiu I	65,976
Mitkof I	5,221
Woewodski I	2,316
Mainland	8,419
Sub-total	154,718
Wrangell Ranger District	
Etolin I	16,169
Wrangell I	9,151
Zarembo I	4,209
Woronofski I	441
Mainland	13,023
Sub-total	42,993
Ketchikan Area Total	***123,009***
Craig Ranger District	
Prince of Wales I	23,957
Dall I & Sumez I	1549
Noyes I, Baker I & Lulu I	1,081
SukkwanI & Long I	557
Sub-total	27,144
Ketchikan Ranger District	
Revillagigedo I	14,608
Gravina I & Duke I	826
Mainland	13,748
Sub-total	29,182

Ketchikan Area (continued)	Acres
Thorne Bay Ranger District	
Prince of Wales I	28,431
Kosciusko I	10,349
Heceta I	754
Coronation I & Warren I	1,414
Sub-total	40,948
Misty Fjords Nat'l Mon. Wilderness	
Revillagigedo I	8,990
Mainland	16,745
Sub-total	25,735
NATIVE LAND	***19,130***
Prince of Wales I	8,281
Dall and Sumez I	721
Kupreanof I	4,358
Baranof and Kruzof I	390
Chichagof I	871
Revillagigedo I	2,285
Annette I	971
Kuiu I	99
Mainland	877
Noyes I, Baker I, & Lulu I	239
Sukkwan I & Long I	38
STATE & PRIVATE LAND	***21,557***
Admiralty I	9
Baranof I	3,101
Dall and Sumez I	61
Chichagof I	1,110
Gravina I	1,087
Mitkof I	1,392
Kosciusko I	117
Kuiu I	764
Kupreanof I	1,458
Prince of Wales I	3,942
Wrangell area	1,227
Revillagigedo	3,744
Kruzof I	298
Other Mainland	3,247
Other Federal	***322***
Baranof I	322
Total Land Affected	***478,453****

*Acreage by ownership was tabulated using Alaska land status data from State of AK, Department of Natural Resources. In prior years a different ownership layer was used to tabulate this information. Other changes in acreage figures are due to a change in the resource, refined sketch-mapping or changes in GIS techniques.

Avalanche Damage

The winter of 1999-2000 was noted nationally for the number of avalanches that occurred in Alaska. Many areas that experienced avalanches are what experts call "one-in a hundred year" (where an avalanche occurs approximately every 100 years) chutes. Within that 100-year time span, many of these chutes become forested and the force of the avalanche snaps those trees in its path. While many of the trees killed were hardwoods, some were also spruce. With the high population of spruce beetle already in south-central Alaska, these dead spruce trees might serve as ideal breeding habitat.

Water Damage

Flood damage was minimal in 2000. Approximately 452 acres were noted in 17 scattered locations across the state. Flood damage is expected to increase in 2001 due to high water flow noted in the Matanuska – Susitna River valley (B5) in July 2000. This is not uncommon as flood damage occurs annually to conifer and hardwood stands adjacent to rivers and lakes on the Alaska mainland.

Hemlock Fluting

Deeply incised grooves and ridges extending vertically along boles of western hemlock characterize hemlock fluting. Fluting is distinguished from other characteristics on tree boles, such as old callusing wounds and root flaring, in that fluting extends near or into the tree crown and fluted trees have more than one groove. Bole fluting is common on western hemlock in many areas of southeast Alaska. This condition reduces the value of hemlock logs because they yield less sawlog volume and bark is contained in some of the wood. The cause of fluting is not completely understood, but associated factors include: increased wind-firmness of fluted trees, shallow soils, and a triggering mechanism during growth release (e.g., some stand management treatments). The asymmetrical radial growth appears to be caused by unequal distribution of carbohydrates due to the presence of dead branches. Researchers have documented the development of fluting in young hemlock stands that regenerated following clearcut harvesting or other disturbance. After several centuries, fluting sometimes is no longer outwardly visible in trees because branch scars have healed over and fluting patterns have been engulfed within the stem.

Bole fluting has important economic impact, but may have little ecological consequence beyond adding to windfirmness. The deep folds on fluted stems of western hemlock may be important habitat for some arthropods and the birds that feed upon them (e.g., winter wren).

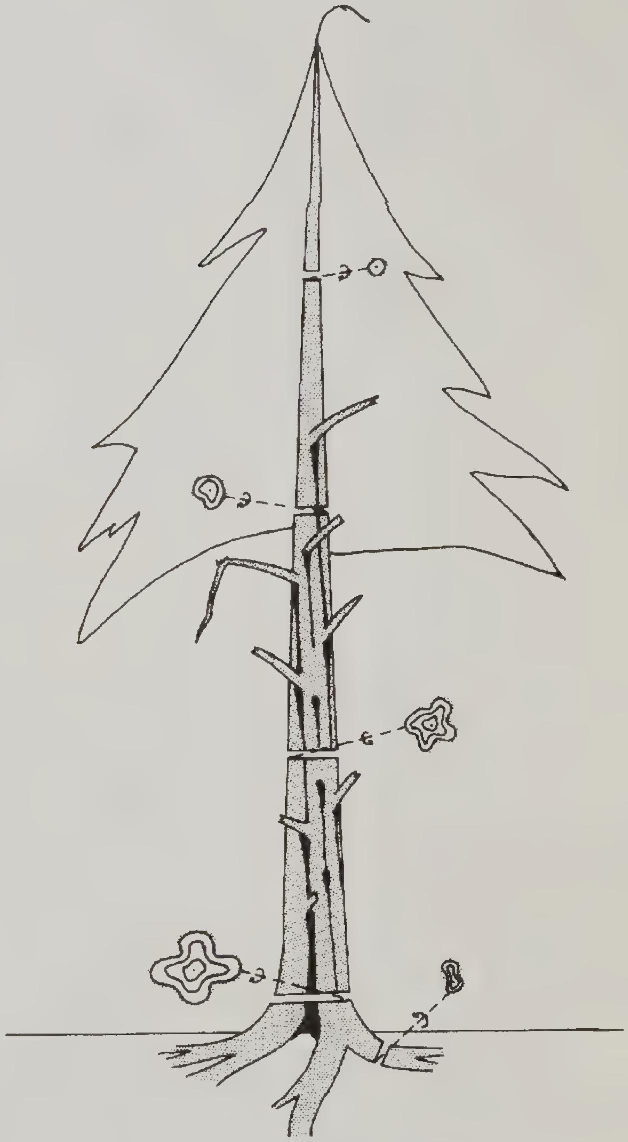

Figure 30. Hemlock fluting branches disrupt the vertical flow of carbohydrate in the stem causing annual rings to become asymmetrical. Flutes originate beneath decadent branches and extend downward, forming long grooves where other branches are intersected. ***(Figure and caption from Julin, K.R.; Farr, W.A. 1989. Stem Fluting of Western Hemlock in Southeast Alaska).***

STATUS OF ANIMAL DAMAGE

Moose
Alces alces

At many locations across south-central and interior Alaska, moose damage hardwoods by repeatedly browsing stems and wounding tree boles. Heavy, repeated browsing on the bole of live trees, particularly aspen and willow, results in broken branches, wounds and stunted malformed stems. Wood decay fungi are known to invade trunk wounds caused by moose.

Snowshoe Hare
***Lepus* sp.**

Bole wounds, terminal and lateral bud damage, and seedling mortality were attributed to browsing by snowshoe hares on hardwoods and conifers in the interior this year. Old damage to mature trees and new damage to seedlings was evident in surveys of pre-commercially thinned white spruce stands near Tok. Years ago, hare browsing killed the main stem; the characteristic angled browse mark is still evident on the dead leader. Live mature trees retain the dead leader but have a pronounced stem crook at the point where a lateral branch became dominant following leader death. The dead leaders provided an infection court for heart rot decay by *Phellinus chrysoloma*. New terminal and lateral bud browsing was evident on white spruce, paper birch, and aspen seedlings across the Interior. Recovery potential of trees following severe browsing in not known.

Porcupine
Erethizon dorsatum

Porcupines cause severe damage to Sitka spruce and western hemlock trees in numerous local areas of southeast Alaska. An extensive survey has documented the level of porcupine damage in young-growth stands. Feeding injuries to trees are confined to the known distribution of porcupine. Damage is especially serious on Mitkof Island in southeast Alaska. Other damage has been noted at Thomas Bay, Cleveland Peninsula, Bradfield Canal, Anita Bay and other areas of Etolin Island, Douglas Island, and the Juneau area (M4). Porcupines also damage trees throughout interior Alaska. Bark beetles, including *Ips* spp., have been found infesting the damaged trees.

In southeast Alaska, the feeding behavior of porcupines changes as forests develop and trees become larger and older. Porcupines climb smaller trees and kill or cause topkill by removing bark along the entire bole, or the bole near the top of the tree. As trees become larger, around 40-50 years old, most of the damage is in the form of basal wounding. Most of these larger trees are not killed, but the large basal scars allow fungi to enter the bole and begin to cause wood decay.

The primary ecological consequences of porcupine feeding are: (1) to provide greater diversity of structure and vegetation in young, even-aged conifer stands through mortality and (2) to provide greater levels of heart rot decay by wounding older trees. This latter effect can alter mortality patterns in old forests as trees may often die through bole breakage.

Bear
Ursus arctos
Ursus americanus

Yellow-cedar trees were wounded in the spring by brown bears on Baranof and Chichagof Islands (M4). Brown bears rip the bark away from the lower boles of these trees, apparently to lick the sweet cambium. The majority of yellow-cedar trees in some stands have basal wounds from bear feeding. Other tree species in southeast Alaska are unaffected. Black bears caused injury to the lower boles of white and Lutz spruce and occasionally aspen in the lowland forests of the Kenai Peninsula (B5). Trees with old scars may have associated columns of wood decay.

APPENDICES

INTEGRATED PEST MANAGEMENT .... A

SUBMITTING INSECTS AND DISEASES FOR IDENTIFICATION .... B

BIOLOGICAL EVALUATIONS, TECHNICAL REPORTS, AND PUBLICATIONS C

ECOMAP SECTION DESCRIPTIONS .... D

WORLD WIDE WEB LINKS .... E

INFORMATION AVAILABLE FROM STATEWIDE AERIAL SURVEYS .... F

INTEGRATED PEST MANAGEMENT

Integrated pest management (IPM) has been described as a "systems approach to alter pest damage to acceptable levels through a variety of techniques, including predators and parasites, genetically resistant hosts, natural environmental modifications, and when necessary and appropriate, chemical pesticides." Current IPM activities in Region 10 include:

- Participation in a cooperative effort with the Alaska Cooperative Extension Service (ACES) to provide pest management information to Alaska residents. The program, which completed its 20th season, includes education, research and survey activities, also provides integrated pest management information concerning urban forestry as well as garden and greenhouse pests. The program is educational in nature and provides the public with a means to learn about pest management in an informal and accessible manner. In 2000, IPM Technicians were located in Fairbanks, Delta, Palmer, Anchorage, and Soldotna. The Anchorage office had two full time technicians; the remaining locations had one seasonal IPM Technician from May through the end of September. The total recorded client contacts reached more than 4500. Technicians conducted more than 1,200 educational contacts including workshops, more than sixty media contacts (newspaper articles, television and radio "spots"), more than 300 site visits, and more than 2,500 clients assisted via phone calls and walk-in requests. More than 50% of the IPM Technician activities occurred in the Anchorage Bowl; home to over 40% of the state population.

- A spruce beetle antiaggregant (MCH) field study utilizing a new release system developed by Med-E-Cell (San Diego, CA) was undertaken in 2000. MCH is precisely released into the atmosphere with this device that is powered by a programmable battery. Previous MCH field studies used release devices that were dependent upon ambient temperature for the release of MCH. Thus, the amount of MCH being released varied significantly from day to day resulting with disappointing results. The 2000 field study was successful; plots treated with MCH delivered through the Med-E-Cell device averaged less than two attacked trees per acre. Untreated plots averaged ten attacked trees per acre. We will continue to test this release device in 2001.

- The attractant semiochemical blend of *Ips perturbatus* was determined from field and laboratory studies to be a combination of *cis*-verbenol, ipsdienol, and ipsenol. Laboratory analysis determined that adult *I. perturbatus* also produce verbenone; a known anti-aggregant semiochemical of other species of *Ips*. A field test was conducted in 2000 with the objective of determining the effectiveness of verbenone as an anti-aggregant. The addition of verbenone to traps baited with the attractant semiochemical blend significantly reduced (by a factor of ten) the number of beetles trapped. We plan to conduct another field study in 2001 using a slow release formulation of verbenone to deter dispersing *Ips* beetles from attacking fresh logging debris.

- A field survey and retrospective study is currently underway on the Kenai Peninsula to determine impacts of primary and secondary bark beetles on residual spruce in harvested stands and stands that have received heavy spruce beetle mortality during the 10 plus year epidemic.

- Yellow-cedar wood is often devalued because of dark-staining. Some evidence suggests that insects are involved in introducing a dark-staining fungus. Wood boring insect tunnels of woodwasps were found in association with the dark stained areas. Since these wood wasps are believed to have only a one year life cycle, many of them can be reared from infested logs and isolations can be made from the sac at the base of the ovipositor (of the females). It can then be determined if dark-stain fungi are being inoculated into trees at the time of egg laying. Wood wasps in other tree species are known to introduce decay fungi. Isolations reveled *Sporidesmium* sp. and *Phialophora melinii* as two of the most common dark fungi.

- The spread and intensification of hemlock dwarf mistletoe is currently under study in even-aged stands, stands that have received different selective harvest treatments, and stands that experienced extensive wind damage in

the 1880s. Plots within these stands have been used to quantify the short, medium, and long-term effects of the disease under different selective harvesting strategies. Results show a substantial difference by stand management. Impact of the disease is light to absent in later developmental stages of even-aged forests but can be severe in forests under some forms of selective harvesting. This indicates a wide range of disease severity that can be related to simple measures of inoculum load at the time of harvest. Distances and intensities of spread are being determined to provide information so that managers can design appropriate harvesting scenarios in relation to expected disease levels. The influence of the disease on tree growth and mortality is also under investigation.

SUBMITTING INSECTS AND DISEASES FOR IDENTIFICATION

The following procedures for the collection and shipment of specimens should be used for submitting samples to specialists:

I. Specimen collection:

1. Adequate material should be collected
2. Adequate information should be noted, including the following:
    a. Location of collection
    b. Date of collection
    c. Who collected the specimen
    d. Host description (species, age, condition, # of affected plants)
    e. Description of area (e.g., old or young forest, bog, urban);
    f. Unusual conditions (e.g., frost, poor soil drainage, misapplication of fertilizers or pesticides?).
3. Personal opinion of the cause of the problem is very helpful.

II. Shipment of specimens:

1. General: Pack specimens in such a manner to protect against breakage.
2. Insects: If sent through the mail, pack so that they withstand rough treatment.
    a. Larvae and other soft-bodied insects should be shipped in small screw-top vials or bottles containing at least 70% isopropyl (rubbing) alcohol and 30% water. Make certain the bottles are sealed well. Include in each vial adequate information, or a code, relating the sample to the written description and information. Labels inserted in the vial should be written on with pencil or India ink. Do not use a ballpoint pen, as the ink is not permanent.
    b. Pupae and hard-bodied insects may be shipped either in alcohol or in small boxes. Specimens should be placed between layers of tissue paper in the shipping boxes. Pack carefully and make certain that there is very little movement of material within the box. Do not pack insects in cotton.
3. Needle or foliage diseases: Do not ship in plastic bags. Sprinkle lightly with water before wrapping in newspaper. Pack carefully and make sure that there is very little movement of material within the box. Include the above collection information. For spruce and other conifers, include a description of whether current year's-needles, last-year's needles, or old-needles are attacked.
4. Mushrooms and conks (bracket fungi): Do not ship in plastic bags. Either pack and ship immediately, or first air dry and then pack. To pack, wrap specimens in dry newspaper and pack into a shipping box with more newspaper. If on wood, include some of the decayed wood. Be sure to include all collection information.

III. Shipping:

1. Ship as quickly as possible, especially if specimens are fresh and not air-dried. If samples cannot be shipped rapidly, then store in a refrigerator.
2. Include return address inside shipping box.
3. Mark on outside: "Fragile: Insect-disease specimens enclosed. For scientific purposes only. No commercial value."

BIOLOGICAL EVALUATIONS, TECHNICAL REPORTS, AND PUBLICATIONS

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ALASKA ECOREGION DESCRIPTIONS

The ecoregions of Alaska and neighboring territories are briefly described below. These descriptions are abbreviated versions of those given by Nowacki and all (2000). They reflect the results of an interagency effort to unify the designations given in Gallant and all (1995) and Nowacki and Brock (1995). Climate, surficial geology, and vegetation communities are described in a tri-archical format.

Polar

Arctic Tundra: These open, wind-swept lands are gripped by polar conditions year around. Temperatures fluctuate substantially among seasons, though always cold. Mean monthly temperatures in the summer generally do not surpass 10°C – a threshold that approximately delimits tree growth. The cold is reinforced by sea-ice that hugs the shorelines over much of the year. The severe atmospheric cold limits water-holding capacity, thus depriving this area of precipitation (<50cm/yr). Even so, surfaces are often moist or wet due to thick permafrost that impedes drainage. These high-latitude areas are covered by tundra dominated by tussock sedges, mosses and low shrubs.

> ***Beaufort Coastal Plain (P9):*** This treeless, wind-swept plain gradually ascends from the Arctic Ocean to the foothills of the Brooks Range. Unconsolidated deposits of marine, fluvial, and glacial origin overlay thick layers of continuous permafrost. There is a lack of bedrock control so the physiography is flat. The moist and wet sedge tussock tundra is comprised mainly of sedges, herbs, and mosses. Low shrubs occur mostly in small drainages where microtopography allows deeper rooting.

> ***Brooks Foothills (P1)*:** These dissected hills and ridges form the northern flank of the rugged Brooks Range as it descends toward the Beaufort Coastal Plain. The surface is underlain by thick continuous permafrost and displays ice-related features such as pingos, solifluction lobes, ice-wedge polyons, and stone stripes. Soils in the active permafrost layer are fairly wet. Moist tussock sedge tundra spans across the landscape interspersed with willow communities along river corridors.

> ***Brooks Range (P3):*** This rugged, east-west trending range represents the northern extension of the Rocky Mountains. The dry polar climate coupled with underlying permafrost make growing conditions difficult for plant life, particularly at high elevations or on steep slopes with active scree movement. Alpine, moist, and tussock tundra of lichens, sedges, and ericaceous plants exist where conditions permit (lower summits and mountainsides). The arctic tree line enters larger drainages along the south portion of the Brooks Range. Here, taller shrub communities fringe these forested valleys.

Bering Tundra: These wind-swept lands occur in and adjacent to the Bering Sea. Here, the sea influences the polar climate only a limited extent (slight temperature moderation and increase in summer precipitation) because of its inherent coldness and long presence of sea ice during the year. With sea ice descends a common Arctic denizen, the polar bear, into the northern reaches of the Bering Sea. Temperatures are cold year around allowing, for the most part, only low growing tundra vegetation to grow. Scattered patches of spruce occur along rivers in the eastern portion of the region.

> ***Kotzebue Sound Lowlands (P5):*** Shaped by past sea-level fluctuations, the land was once connected to Siberia and formed a part of a large unglaciated area called Beringia during glacial periods when water was locked in continental ice sheets and sea levels were low. Today, this flat plain of marine sediments, deltas, and low-lying glacial till is limited to a rim of lowlands surrounding the Kotzebue Sound. Much of the area is covered by a thick loess blanket blown off nearby outwash plains during glacial periods. Thawing permafrost is widespread, creating a thaw-lake cycle that forms a diverse mosaic of wetlands including marshes, wet meadows, riparian shrublands, and intervening ridges with tussock tundra as lakes form and drain, and ground ice aggrades in the exposed sediments.

> ***Seward Peninsula (P4):*** This cold, wind-swept landmass jutting out into the Bering Sea represents the southernmost haunt of polar bears on mainland Alaska. Sedimentary, metamorphic, and volcanic rocks intertwine to form a landscape mosaic of coastal lowlands, expansive convex hills with scattered broad

valleys, and small, isolated groups of rugged mountains. Vegetation is principally tundra, with alpine Dryas-lichen tundra and barrens at high elevations and moist sedge-tussock tundra at lower elevations. Patches of low-growing ericaceous and willow-birch shrubs occur on better-drained areas. Scattered spruce occur along river drainages on the extreme eastern edge of the region. Permafrost is continuous but oscillates from thin to moderately thick. Soils are often wet, shallow, and organic due to permafrost.

Bering Sea Islands (P7): These treeless rocky volcanic islands are scattered thoughout shallow portions of the Bering Sea. Here, a peculiar mix of polar and maritime climates exist dependent on season. Thin to moderately thick permafrost underlies mainly thin, rocky soils. Moist tundra communities of sedges, grasses, low shrubs and lichens are surrounded by rocky cliffs and shorelines.

Bering Taiga: These open coastal areas bordering the Bering Sea are dominated by cold, seasonally-moist, subpolar conditions. During the summer, moisture is derived from the adjacent Bering Sea and carried on land by the prevailing westerlies. Summers are sufficiently long and warm enough to allow patches of stunted trees (i.e., taiga) to grow primarily along rivers and streams. However, summer warming is tempered by the cold prevailing winds off the Bering Sea.

***Nulato Hills (P2)*:** These low-rolling hills are the remains of an ancient mountain range after extended periods of downcutting, weathering, and erosion. East of Norton Sound, these hills ripple inland in a southwest-northeast orientation with streams flowing in intervening valleys. Vegetation patterns generally follow the terrain, with alpine Dryas-lichen tundra and moist sedge-tussock tundra on hilltops grading into short then tall willow-birch-alder shrublands and eventually spruce woodlands at progressively lower elevations. Permafrost is continuous but oscillates from thin to moderately thick.

Yukon-Kuskokwim Delta (P8): The Yukon and Kuskokwim rivers nourish this vast marshy plain as they fan out to meet the Bering Sea. Marine sediments and alluvium principally underlie this flat, lake-studded lowland. Isolated basalt hills and volcanic cinder cones jut up in places. Moderately thick to thin permafrost underlies wet and shallow organic soils. Many low-gradient streams meander dynamically across the surface. Moist tundra communities of sedge, herbs, grasses and lichens predominate with shrubs and scattered trees occurring near rivers and on hills.

Ahklun Mountains (P10): This coastal group of rugged steep-walled mountains spans two expansive wetland complexes (Yukon-Kuskokwim Delta and Bristol Bay Lowlands) along the southern Bering Sea. Here, mountain glaciers coalesced during the Pleistocene ice age and carved many broad U-shaped valleys. On the south side of the mountains, these valleys have subsequently filled with water forming large "finger" lakes. Dwarf shrub-lichen tundra dominates mountain crests and upper slopes where permafrost is discontinuous. Shrubs (willows, birches, and alders) become progressively more abundant and robust at lower elevations as permafrost becomes more fragmented. In valleys, shrublands are punctuated by sedge-tussock tundra meadows and mixed forests.

***Bristol Bay Lowlands (P6)*:** This flat to gently-rolling lowland is comprised mainly of glacial till and outwash deposited by various Pleistocene glaciers from the surrounding Ahklun Mountains and Aleutian Range. This basin is underlain with mixes of glacial, alluvial, and marine sediments all cloaked with varying amounts of loess. Permafrost occurs in scattered isolated masses. Wet organic soils support low and dwarf shrub communities of willow, birch, and alder. Mosses and lichens are abundant groundcovers.

Boreal

Intermontane Boreal: These areas experience extreme seasonal temperature changes from long, cold winters to short, moderately-warm summers. Boreal woodlands and forests cover much of this undulating landscape. The continental climate is fairly dry throughout the year and forest fires rage during summer droughts. This intermontane terrain sandwiched between the Brooks and Alaska Ranges remained largely ice-free during the last ice age, forming part of the "Beringia Corridor".

Kobuk Ridges and Valleys (B12): A series of paralleling ridges and valleys radiate southwards from the Brooks Ranges. Permafrost of thin to moderate thickness underlies most of the area. Forests and woodlands dominate much of valley bottoms and mountainsides with black spruce in wetland bogs, white spruce and balsam poplar along rivers, and white spruce, birch, and aspen on well-drained uplands. Tall and short shrublands of willow, birch, and alder communities occur in ridges. Trees become increasingly sparse, less robust, and restricted to lower elevations in the west – here forest succession is slowly progressing along rivers (e.g., lower Noatak River).

Ray Mountains (B2): The Ray Mountains are an overlapping series of compact, east-west trending ranges underlain by Ruby terrane. The metamorphic bedrock is usually covered with rubble and soils are subsequently shallow and rocky. Permafrost is generally discontinuous and ranges from thin to moderate thickness. Open scrubby forests of spruce and aspen interspersed with tall shrublands prevail over much of the area. Low shrubs and alpine tundra progressively dominate at higher elevations. Forest fires are common in the summer.

Davidson Mountains (B14): Along the south flank of the eastern Brooks Range lie rugged mountains dissected by broad floodplains of glacial origin. The mountains are draped by course rubble whereas river valleys and floodplains are lined with unconsolidated glacial and alluvial sediments. Continuous permafrost from thin to moderate thickness underlies most of the area. Boreal forests cover much of the terrain with black spruce in bogs, white spruce and balsam poplar along rivers, and white spruce, birch and aspen on uplands. Tall willow, birch, and alder communities also occur. Forest fires are frequent.

Yukon-Old Crow Basin (B6): This gently-sloping basin along the Porcupine River is comprised of terraces, hilly moraines, and mountain toeslopes that ring the Yukon and Old Crow Flats. The marshy flats have developed in deep alluvial and glaciolacustrine deposits underlain by discontinuous permafrost. The poorly-drained flats and terraces harbor vast wetlands pockmarked with dense concentrations of thaw lakes and ponds. Opaque with glacial silts and shoreline mud, the Yukon River forms an aquatic maze of islands, sandbars, and back sloughs as it crisscrosses the lower flats. Vegetation varies with soil drainage grading from wet grass marshes and low shrub swamps to open black spruce forests to closed spruce-aspen-birch forests on better-drained uplands. Summer forest fires are common.

North Ogilvie Mountains(B15): This terrain consists of flat-topped hills and eroded remnants of a former plain. Sedimentary rocks, especially limestone, underlie most of the area. Shallow soils have developed in rocky colluvium on mountainsides where landslides, debris flows, and soil creep frequently occur. On lower slopes, soils are deeper, moister, and underlain by extensive permafrost. Low shrub tundra of willow, alder, and birch and aspen and spruce woodlands occur at lower elevations. These mountains are the source of many streams that eventually feed the Porcupine, Yukon, and Peel rivers. Lakes are relatively rare.

Yukon-Tanana Uplands (B13): These dissected mountains are of moderate height. The topography of smooth-topped ridges deeply incised by narrow valleys is indicative of a lack of glaciation in the past. Permafrost is discontinuous but widespread, and is particularly abundant on moist lower slopes and valley bottoms. This area straddles treeline with vegetation ranging from alpine tundra on ridges and upper slopes to boreal forests on lower slopes and valleys. Stunted black spruce woodlands occur on cold, north-facing slopes whereas mixed forests (spruce, aspen, birch, poplar) occur on warm south-facing slopes. This area includes the highest incidence of lightening strikes in the Yukon and forest fires are consequently frequent.

Tanana-Kuskokwim Lowlands (B10): This alluvial plain slopes gently northward from the Alaska Range. Streams flowing across this north-sloping plain ultimately drain into one of two large river systems -- the Tanana or Kuskokwim. Even though a rain shadow exists due to the neighboring Alaska Range, surface moisture is rather abundant due to the gentle topography and poor soil drainage due to underlying permafrost. Boreal forests dominate the landscape with black spruce in bogs, white spruce and balsam poplar along rivers, and white spruce, birch, and aspen on hills. Tall willow, birch, and alder communities are scattered throughout.

Yukon River Lowlands (B7): An expansive wetland system occurs along major rivers coursing through central Alaska. Deep deposits of undifferentiated sediments underlie these floodplains, lowlands, and intervening hills. Surface moisture is abundant due to the gentle grade, poor soil drainage, and presence of permafrost. Boreal forests dominate the landscape with black spruce in bogs, white spruce and balsam poplar along rivers, and white spruce, birch, and aspen on hills. Tall willow, birch, and alder communities are scattered throughout. Many flat organic surfaces are pockmarked with dense concentrations of lakes and ponds. This unit is distinguished from the Tanana-Kuskokwim Lowlands by having lower elevations, a slightly wetter climate, and more robust vegetation.

Kuskokwim Mountains (B11): This subdued terrain is comprised of old, low-rolling mountains that have eroded down largely without the aid of recent past glaciations. Mountains are composed of eroded bedrock and rubble whereas intervening valleys and lowlands are comprised of undifferentiated sediments. Thin to moderately thick permafrost underlies most of the area. Boreal forests dominate grading from white spruce, birch, and aspen on uplands to black spruce and tamarack in lowlands. Tall willow, birch, and alder shrub communities are scattered throughout, particularly where forest fires burned in the recent past. Rivers meander through this undulating landscape following fault lines and highly eroded bedrock seams.

Alaska Range Transition: Boreal forests occur within the basins and troughs fringed by the Alaska Range. This area is considered transitional since some climatic moderation is afforded by the nearby Pacific Ocean (i.e., maritime moisture). Ice sheets heavily scoured this area during the last glaciation and small ice caps and glaciers still exist at high elevations.

Lime Hills (B4): The Lime Hills are glacially-dissected mountains descending from the west side of the Alaska Range. The ridges and mountainsides are covered with colluvial rubble whereas the valleys contain glacial moraines and outwash with some alluvial deposits along rivers. The continental climate is moderated somewhat by maritime influences of the Bering Sea and North Pacific Ocean. The area is underlain by isolated masses of permafrost. Vegetation is predominately tall and low shrub communities of willow, birch, and alder. Spruce forests and woodlands confined to valley bottoms and mountain toeslopes.

Alaska Range (B3): A series of accreted terranes conveyed from the Pacific Ocean have fused to form this arcing mountain range. Landslides and avalanches frequently sweep the steep, scree-lined slopes. Discontinuous permafrost underlies shallow and rocky soils. Because of its height, a cold continental climate prevails and much of the area is barren of vegetation. Occasional streams of Pacific moisture are intercepted by the highest mountains and help feed small icefields and glaciers. Alpine tundra occurs on mid and upper slopes. Shrub communities of willow, birch, and alder occupy lower slopes and valley bottoms. Forests are relegated to the low-elevation drainages.

***Cook Inlet Basin (B5)*:** This gently-sloping lowland has been buried by ice and flooded by proglacial lakes several times during the Pleistocene. As such, the basin is comprised of fine-textured lacustrine deposits ringed by coarse-textured glacial tills and outwash. Numerous lakes, ponds, and wetlands occur. The basin is generally free of permafrost. A mix of maritime and continental climates prevail with moderate fluctuations of seasonal temperature and abundant precipitation. This climate coupled with the flat to gently-sloping, fine-texture surfaces give rise to wet, organic soils clothed with black spruce forests and woodlands. Ericaceous shrubs are dominant in open bogs. Mixed forests of white and Sitka spruce, aspen and birch occur on better-drained sites and grade into tall shrub communities of willow and alder on slopes along the periphery of the basin.

Copper River Basin (B8): This mountain basin lies within the former bed of Glacial Lake Ahtna on fine-textured lacustrine deposits ringed by coarse glacial tills. The basin is a large wetland complex underlain by thin to moderately thick permafrost and pockmarked with thaw lakes and ponds. A mix of low shrubs and black spruce forests and woodlands clothe the wet organic soils. Cottonwood, willow, and alder line rivers and streams as they braid or meander across the basin. Spring floods are common along drainages. The climate is strongly continental, with steep seasonal temperature variation. The basin acts as a cold-air sink and winter temperatures can get bitterly cold.

Coast Mountains Transition: The high mountains on the interior-side of the Coast Mountains are exposed to a peculiar mix of climates. Because of their sheer height, these mountains capture ocean-derived moisture as it passes inland. Yet, due to their proximity to the Interior, these mountains possess a fair degree of seasonal temperature change similar to a continental climate. Climatic influences change with elevation, with maritime conditions on mountaintops (feeding ice caps and glaciers) grading to continental conditions at their base (boreal forests).

Wrangell Mountains (B9): This volcanic cluster of towering, ice-clad mountains occurs at the northwest edge of the St. Elias Mountains. The Wrangell Mountains possess a peculiar mix of climates because of their size and geographic location (i.e., on the Interior-side of the Coastal Mountains). The abundant maritime snows feed extensive ice fields and glaciers interspersed by dull gray ridges draped with rock shard slopes and patches of alpine meadows. The climate grades to a dry continental at lower elevations where the Wrangell Mountains abut the cold-air basin of the Copper River. Shrublands of willow and alder with scattered spruce woodlands ring the lower slopes. Spruce and cottonwood occur along larger drainages. The Wrangell Mountains are highly dynamic due to active volcanism, avalanches, landslides, and stream erosion. Soils are thin and stony and underlain by discontinuous permafrost.

Kluane Range (B1): The Kluane Range encompasses the drier interior portion of the St. Elias Mountains spanning from the ablation zone (area where glacial ice melts faster than it accumulates) eastward to a fault line scarp along the Shakwak Valley. The area has a dry continental climate. It lies within a partial rainshadow of the St. Elias Mountains whereby moisture from the Pacific Ocean is effectively rung-out of the atmosphere on its accent over these towering peaks. The high-relief topography has been exposed to mass wasting, stream erosion and glacial scouring. Swift streams cascade down steep mountainsides where scree movement, rock falls, landslides, and soil creep actively occur. Permafrost is discontinuous. Vegetation is comprised principally of alpine tundra and barrens of lichens, prostrate willows, and ericaceous shrubs. Taller shrub communities occur at mid elevations. White spruce is found on lower slopes and valleys along the eastern boundary.

Maritime

Aleutian Meadows: This peninsula and associated island arc divides the cold and stormy waterbodies of the North Pacific Ocean and Bering Sea. Harsh weather conditions prevail over these exposed landscapes including high winds, persistent clouds, rain and fog, and salt spray. This volcanic arc, built along the Pacific Plate Subduction Zone, is one of the most seismically active in the world. The vegetation is comprised mainly of shrub and herbaceous plants that can tolerate the stressful growing conditions.

Alaska Peninsula (M7): The Aleutian Range serves as the spine of this peninsula which divides Bristol Bay from the North Pacific Ocean. The folded and faulted sandstone bedrock is dotted with symmetrical cinder cones clad with ice, pumice, and volcanic ash. Earthquakes are common and some of the most active volcanos on the continent occur here. The Pleistocene Glaciation has produced strongly contrasting topographies along this peninsula with smooth glacial moraines and colluvial shields on the north side and rugged deeply-cut fjordlands on the south side. Dominant vegetation is low shrublands of willow, birch, and alder interspersed with ericaceous/heath and Dryas-lichen communities. Alpine tundra and glaciers occur on mountaintops. Spruce forests occur along the shores at the mouth of Cook Inlet and within the northern reached of this region.

Aleutian Islands (M1): These fog-shrouded islands represent volcanic summits of a submarine ridge extending from the Alaska Peninsula to the Kamchatka Peninsula. It is one of the most seismically and volcanically active areas in the world. These islands are free of permafrost, covered by volcanic-ash soils, and dissected radially by short, swift streams. Terrestrial warming is subdued by incessant cold ocean winds and perpetual overcast clouds and fog, which limits solar insolation. The flora is a blend of species from two continents, grading from North American to Asian affinities from east to west. Mountain flanks and coastlines dominated by low shrubs of willow, birch, and alder interspersed with ericaceous-heath, Dryas-lichen, and grass communities. Alpine tundra and glaciers occur on mountains.

APPENDIX D

Coastal Rainforests: These coastal areas adjacent to the North Pacific Ocean receive copious amounts of precipitation throughout the year. Seasonal temperature changes are limited due to proximity to open ocean. A cool, hypermaritime climate dominates with minor seasonal temperature variation and extended periods of overcast clouds, fog, and precipitation. These areas warm sufficiently in the summer to allow trees to grow and dominate at lower elevations. Massive ice fields and glaciers are common in the mountains.

Alexander Archipelago (M4): This island-rich fjordland formed when the glacier-carved landscape filled with seawater after deglaciation. Rounded mountains with rolling till plains occur where continental glaciers overrode the land whereas angular mountains exist where continental glaciers did not. Glacial rebound has raised marine terraces where rich coastal lowlands and estuaries now exist. Winter snow, though abundant in locations, is ephemeral at sea level. Lush, lichen-draped temperate rain forests of hemlock and spruce blanket the shorelines and mountain slopes where soil drainage affords. Open and forested wetlands occur on poorly-drained soils especially on compact glacial tills, marine terraces, and gentle slopes. On upper slopes, forests progressively give way to shrublands, landslide and avalanche tracks, and alpine tundra.

Boundary Ranges (M2): A northwest-southeast trending batholith of resistant granite and granodiorite underlies this portion of the Coast Mountains. Abundant maritime snows feed huge icefields and glaciers that form an undulating matrix around exposed, rugged peaks called nunataks. Summer meltwaters accumulate and flow across these icefields and glaciers, often plunging into deep, icy crevasses called moulins. The southern most extent of tidewater glaciers on the North American continent occurs here. Only a few large rivers (Taku and Stikine Rivers) manage to breach this mountain range from the Interior. These, together with smaller streams, support large salmon runs of all five Pacific species. Alpine tundra habitats consist of sedges, grasses, and low shrubs.

Chugach-St. Elias Mountains (M6): Arcing terranes of Pacific origin have been thrusted onto the North American continent forming a rugged ice-clad mountain chain that surrounds the Gulf of Alaska. This is the largest collection of ice fields and glaciers found on the globe outside the polar region. The steer height of these mountains together with their expansive ice fields forms an effective barrier for Interior species except along the Alsek and Copper River corridors. Thin and rocky soils exist where mountain summits and slopes are devoid of ice, snow, and active scree. Here, alpine communities of sedges, grasses, and low shrubs grow. Deeper soils have formed in unconsolidated morainal and fluvial deposits underlain by isolated pockets of permafrost in broad u-shaped valleys. Alder shrublands and mixed forests occur on lower slopes and valley floors.

Gulf of Alaska Coast (M5): The northern shorelines and adjacent mountain slopes along the Gulf of Alaska form this region. A fjordal coastline and archipelago exists around Prince William Sound and points west where continental ice sheets repeatedly descended in the past. A coastal foreland extends from the Copper River Delta southeast to Icy Point fringed by the slopes and glacier margins of the Chugach-St. Elias Mountains. Here, unconsolidated glacial, alluvial, and marine deposits have been uplifted by tectonics and isostatic rebound to form this relatively flat plain. Snow is abundant in the winter and persists for long periods at sea level. Permafrost is absent. Lush, lichen-draped temperate rain forests of hemlock and spruce occur where soil drainage occurs, interspersed with open wetlands.

Kodiak Island (M3): This rugged, fjord-carved island complex is a geologic extension of the Chugach Mountains with a similar suite of folded and faulted sedimentary rocks of Pacific origin. During past glaciations, a solid ice sheet spanned Shelikof Strait connecting this group of islands with the mainland. Today, high sharp peaks with cirque glaciers and low rounded ridges overtop glacially-scoured valleys covered with till or lacustrine deposits. The flora of island group is still recovering from the last glaciation. For instance, trees did not survive the last Pleistocene glaciation and only recently has Sitka spruce and black cottonwood managed to regain a foothold on the northeastern portion of this island group. At present, luxuriant forb/grass meadows and willow and alder thickets cover the majority of these islands. Some alpine tundra exists at higher elevations. Snow blankets these islands during the winter from lows sweeping eastward along the Aleutians. These islands are entirely free of permafrost.

APPENDIX D

References:

Gallant, A.L., E.F. Binnian, J.M. Omernik, and M.B. Shasby. 1995. Ecoregions of Alaska. U.S. Geological Survey Professional Paper 1567.

Nowacki, G. and T. Brock. 1995. Ecoregions and Subregions of Alaska, ECOMAP Version 2.0 [map]. USDA Forest Service, Alaska Region, Juneau, AK, scale 1:5,000,000.

Nowacki, G.J., P. Spencer, T. Brock, M. Fleming, and T. Jorgenson. 2001. Ecoregions of Alaska and Neighboring Territories. U.S. Geological Survey Miscellaneous Investigations Series I Map (in press).

WORLD WIDE WEB LINKS

Forest insect and disease survey information and general forest health information:

http://fsweb.r10.fs.fed.us/intranet/staff/spf/fhpr10.htm
USFS, State & Private Forestry, Forest Health Protection site for Alaska with information on Alaskan insects & diseases, bibliography listing, and links to other Forest Health sites. The section presents a program overview, personnel information, current forest insect and disease conditions throughout the state, forest insect and disease biology, control, impacts, Sbexpert software and other Forest Health issues. This Home Page is periodically updated and is a good source of information on Alaska Forest Health issues.

http://www.dnr.state.ak.us/forestry/index.htm
An Alaska Department of Natural Resources, Division of Forestry home page was assembled in late 1996 for the fire and resource management programs. The site is currently under development but information is available on several of Forestry's programs, including forest health and forest insect surveys. Information will be updated as personnel and funding permit. Users may check the site for information relating to forest health. A link is provided on the home page for accessing forest health and insect survey information and to send an e-mail message. The URL for this insect and disease link is **http://www.dnr.state.ak.us/forestry/res_faq.htm.**

http://www.asgdc.state.ak.us
This is the **State of Alaska, Department of Natural Resources' Geographic Data Clearinghouse site** that is directly patterned and linked to the AGDC site maintained at the U. S. Geological Survey, EROS (Earth Resource Observation Satellite) field office in Anchorage--SEE AGDC link below. The State of Alaska-maintained section of this site contains data layers information in the form of metadata, or "data about the data", that describe the content, quality, condition, and other characteristics of the data. The metadata is compliant with federal geographic data committee (FGDC) standards. For example, data on land status, transportation, physical boundaries—such as coastline, conservation units, etc., and links to state resource information (e.g., forest pest damage surveys, Exxon Valdez restoration data, CIIMMS) and links to other agency forest pest and forest health information and data can be found here. The site is not complete since statewide participation for data submission and access links does not exist at this time, however, the goal is to make this a clearinghouse node for state and local agencies. One example of a clearinghouse node, which does presently exist for data about the Kenai Peninsula that has fairly complete agency participation, is the CIIMMS (Cook Inlet Information Management & Monitoring System) site that can be found at **http://www.dec.state.ak.us/ciimms/**

http://agdc.usgs.gov
The **Alaska Geospatial Data Clearinghouse** is a component of the **National Spatial Data Infrastructure (NSDI)**. The Clearinghouse provides a pathway to find geospatial referenced data and associated metadata. The site is a link to data available from a multiple of federal, state and local agencies. The site is currently administered at the U.S. Geological Survey, EROS field office in Anchorage. From this website the Forest Health Monitoring Clearinghouse can be reached.

http://agdc.usgs.gov/data/projects/fhm
The **Forest Health Monitoring Clearinghouse** provides special resource databases of forest health related information to land managers, scientists, and the general public. Fourteen statewide data layers are available for downloading, including Vegetation/land cover, ECOMAP and Ecoregions, Wetlands Inventory, Timber Harvest and other disturbances, Yearly Insect and Disease Damage, Fire History, Fire Protection Zones, Fire Management Boundaries, Fire Fuels Models, Land Status/Ownership, Elevation, Hydrography, Soils, and Permafrost.

http://www.fs.fed.us/r6/nr/fid/fidls/fidl127.htm
An USDA Forest Service Oregon/Washington Home-page. This is a link to the **FIDL publication #127 on the Spruce Beetle** This publication has been recently revised nationally by the U.S. Forest Service and is available in brochure form.

http://www.state.ak.us/local/akpages/FISH.GAME/habitat/geninfo/forestry/INFEST/infesthome.htm
The **Interagency Forest Ecology Study Team (INFEST)** home-page. This site has ecological information pertaining to wildlife and forests, spruce bark beetle, basic silvics, and other Alaska ecosystem considerations.

http://www.bugwood.caes.uga.edu
A site maintained by the University of Georgia on forest and **urban pests**, including a good section on **bark beetles**. This is just one example of some of the insect and disease information resources that can be found on the World Wide Web.

http://www.borough.kenai.ak.us/sprucebeetle/default.htm
Kenai Peninsula Borough Spruce Bark Beetle Web Site. This site supplies a direct link to the Kenai Peninsula Borough's Ecosystem Level **Vegetation Mapping Initiative (ELVMI).** This initiative is a vegetation mapping project to provide detailed vegetation mapping information to support fire risk and hazard management in the aftermath of a major spruce beetle epidemic on the Kenai Peninsula. The site gives a progress update on the mapping project, which is designed to produce a forest health/hazard map and GIS data base.

INFORMATION AVAILABLE FROM STATEWIDE AERIAL SURVEYS

Each year, forest damage surveys are conducted over approximately 30 million acres. This annual survey is a cooperative effort between U.S. Forest Service, State and Private Forestry, Forest Health Protection (S&PF/FHP) and State of Alaska, Department of Natural Resources, Division of Forestry (AKDNR/DOF) forest health staffs to assess general forest conditions on Alaska's 129 million acres of forested area. About 25% of Alaska's forested area is covered each summer using fixed-wing aircraft and trained observers to prepare a set of sketch-maps depicting the extent (polygons) of various types of forest damage including recent bark beetle mortality, various hardwood and conifer defoliation, and abiotic damage such as yellow-cedar decline. A number of other damage types are noted including flooding, wind damage, and landslide areas during the survey. The extent of many significant forest tree diseases, such as stem and root decays, are not estimated from aerial surveys since this damage is not visible from aerial surveys as compared to the pronounced red topped crowns of bark beetle-killed trees.

In this way, forest damage information is sketched on 1:250,000 scale USGS quadrangle maps at a relatively small scale. For example, at this scale one inch would equal approximately 4 miles distance on the ground. When cooperators request specialized surveys, larger scale maps are sometimes used for specific areas to provide more detailed assessments. Due to the short Alaska summers, long distances required, high airplane rental costs, and the short time frame when the common pest damage signs and tree symptoms are most evident (i.e., usually only during July and August), sketch-mappers must strike a balance to efficiently cover the highest priority areas with available personnel schedules and funding.

Prior to the annual statewide forest conditions survey, letters are sent to various state and federal agency and other landowner partners for survey nominations. The federal and state biological technicians and entomologists decide which areas are highest priority from the nominations. In addition, areas are selected where several years' data are collected to establish trends from the year-to-year mapping efforts. In this way, general damage trend information is assembled for the most significant pests and compiled in this annual Conditions Report. The sketch-map information is also digitized and put into a computerized Geographic Information System (GIS) for more permanent storage and retrieval by users.

Information listed in this Appendix is a sample of the types of products that can be prepared from the statewide surveys and GIS databases that are available. Due to the relatively high cost of mass-producing hard copy materials from the survey data, including colored maps, a number of other map products that are available have not been included with this report. In addition, maps which show the general extent of forest insect damage from 2000 and previous statewide aerial surveys, landowner boundaries, and other types of map and digital data can be made available in various formats depending on the resources available to the user:

Submit data and map information requests to:

Roger Burnside, Entomologist
State of Alaska Department of Natural Resources
Division of Forestry Central Office
Resource Section-Forest Health
550 W. 7th Avenue, Suite 1450
Anchorage, AK 99501-3566
Phone: (907) 269-8460
Fax: (907) 269-8902
E-mail: roger_burnside@dnr.state.ak.us

Kathy Matthews, Biotechnician
USDA Forest Service,
State and Private Forestry, Forest
Health Protection
3301 C Street, Suite 522
Anchorage, AK 99503-3956
Phone: (907) 271-2574
Fax: (907) 271-2897
E-mail: kmatthews03@fs.fed.us

APPENDIX F

Map information included in this report: "Forest Insect And Disease Conditions In Alaska -2000"

- **Aerial Detection Survey, Significant Pest Activity,** 11x17 in. format, depicting spruce beetle, *Ips*, spruce aphid, larch sawfly defoliation, willow defoliation and cedar decline "hot spots" (color; showing enhanced representation of damage areas).

- **2000 Alaska Forest Damage Surveys Flight Lines and Major Alaska Landownership Blocks** (includes table listing acres surveyed by landowner based on flight lines flown for the 2000 aerial surveys).

- **Kenai Peninsula Region Spruce Beetle Activity 1995-2000**, 8 ½ x 11 in. format, depicting sequential year-by-year spruce beetle activity in south-central Alaska, including the Kenai Peninsula, Cook Inlet area to Anchorage & Talkeetna (includes vegetation base layer).

- **A Decade of Spruce Beetles: Year 2000**, 8 ½ x 11 in. format, depicting 2000 damage in red and prior damage, 1991-1999 in yellow (includes color shaded relief base showing extent of forest landscape and sample photos of spruce beetle impact).

- **Southeast Alaska Cedar Decline 2000 Aerial Detection Surveys**, 8 ½ x 11 in. format, depicting cumulative Alaska yellow-cedar decline over several years (includes a sample photo of cedar decline. Forested areas are delineated with color shaded relief background)

- **Spruce Aphid and Willow Leaf Blotchminer Defoliation,** 8 ½ x 11 in. format, depicting defoliation of the respective regional areas and 3 years of defoliation by the respective insect (includes color shaded relief base showing extent of forest landscape and sample photos of impact).

[Map data for maps provided by USFS/S&PF and AKDNR, Anchorage; cedar decline data provided by USFS/S&PF, Juneau]

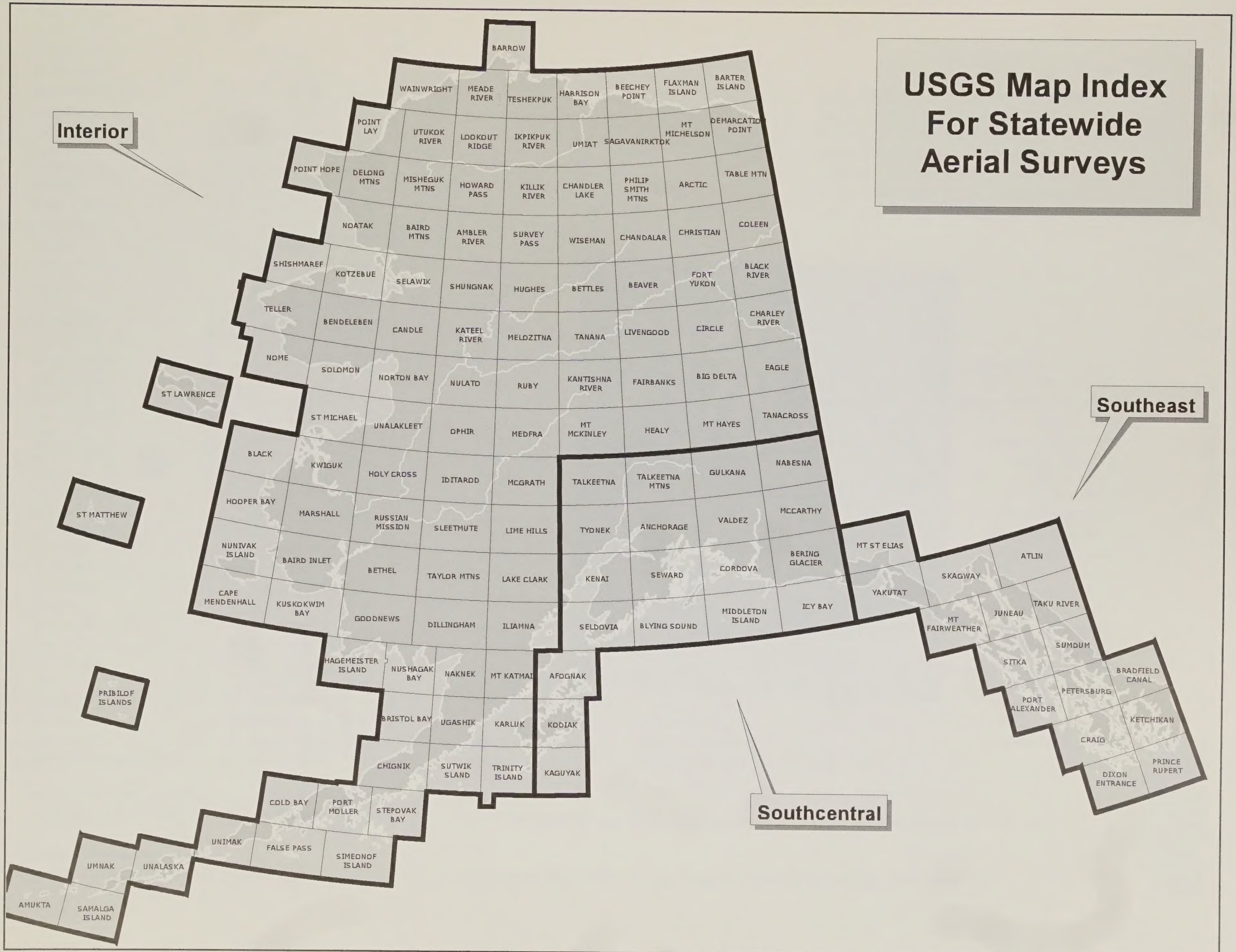
Map and GIS Products Available Upon Request:

1. Digital data file of 1999 forest damage coverage in ArcInfo cover or ArcView shapefile(ESRI, Inc.) format. GIS data files are available at the following URL: **http://agdc.usgs.gov/data/projects/fhm/**.

2. An electronic version of this report, including maps and images, will be available at the Alaska USFS, State & Private Forestry, Forest Health Protection web site (URL: **http://fsweb.r10.fs.fed.us/intranet/staff/spf/fhpr10.htm.**

3. Cumulative forest damage or specific-purpose damage maps prepared from AK/DOF or AK USFS, S&PF, FHP geographic information system database.

4. Forest Insect & Disease Conditions in Alaska CD-ROM (includes most of digital forest damage coverages in the AKDNR/DOF database in viewable formats and a copy of the 2000 Alaska Forest Insect & Disease Conditions Report in .pdf format; a fee may be assessed depending on availability of copies and amount of data required for the project).


USGS Map Index For Statewide Aerial Surveys
Interior
Southeast
Southcentral
BARROW
WAINWRIGHT
MEADE RIVER
TESHEKPUK
HARRISON BAY
BEECHEY POINT
FLAXMAN ISLAND
BARTER ISLAND
POINT LAY
UTUKOK RIVER
LOOKOUT RIDGE
IKPIKPUK RIVER
UMIAT
SAGAVANIRKTOK
MT MICHELSON
DEMARCATION POINT
POINT HOPE
DELONG MTNS
MISHEGUK MTNS
HOWARD PASS
KILLIK RIVER
CHANDLER LAKE
PHILIP SMITH MTNS
ARCTIC
TABLE MTN
NOATAK
BAIRD MTNS
AMBLER RIVER
SURVEY PASS
WISEMAN
CHANDALAR
CHRISTIAN
COLEEN
SHISHMAREF
KOTZEBUE
SELAWIK
SHUNGNAK
HUGHES
BETTLES
BEAVER
FORT YUKON
BLACK RIVER
TELLER
BENDELEBEN
CANDLE
KATEEL RIVER
MELOZITNA
TANANA
LIVENGOOD
CIRCLE
CHARLEY RIVER
NOME
SOLOMON
NORTON BAY
NULATO
RUBY
KANTISHNA RIVER
FAIRBANKS
BIG DELTA
EAGLE
ST LAWRENCE
ST MICHAEL
UNALAKLEET
OPHIR
MEDFRA
MT MCKINLEY
HEALY
MT HAYES
TANACROSS
BLACK
KWIGUK
HOLY CROSS
IDITAROD
MCGRATH
TALKEETNA
TALKEETNA MTNS
GULKANA
NABESNA
HOOPER BAY
MARSHALL
RUSSIAN MISSION
SLEETMUTE
LIME HILLS
TYONEK
ANCHORAGE
VALDEZ
MCCARTHY
ST MATTHEW
NUNIVAK ISLAND
BAIRD INLET
BETHEL
TAYLOR MTNS
LAKE CLARK
KENAI
SEWARD
CORDOVA
BERING GLACIER
MT ST ELIAS
ATLIN
SKAGWAY
YAKUTAT
CAPE MENDENHALL
KUSKOKWIM BAY
GOODNEWS
DILLINGHAM
ILIAMNA
SELDOVIA
BLYING SOUND
MIDDLETON ISLAND
ICY BAY
MT FAIRWEATHER
JUNEAU
TAKU RIVER
SUMDUM
HAGEMEISTER ISLAND
NUSHAGAK BAY
NAKNEK
MT KATMAI
AFOGNAK
SITKA
BRADFIELD CANAL
PORT ALEXANDER
PETERSBURG
PRIBILOF ISLANDS
BRISTOL BAY
UGASHIK
KARLUK
KODIAK
KETCHIKAN
CRAIG
CHIGNIK
SUTWIK ISLAND
TRINITY ISLAND
KAGUYAK
PRINCE RUPERT
DIXON ENTRANCE
COLD BAY
PORT MOLLER
STEPOVAK BAY
UNIMAK
FALSE PASS
SIMEONOF ISLAND
UMNAK
UNALASKA
AMUKTA
SAMALGA ISLAND

Quadrangle Areas Flown During 2000 Statewide Aerial Surveys:

*Quads with no insect damage reported for 2000 are marked with an asterisk.

South-central Alaska
Anchorage
Cordova*
Gulkana*
Kenai
McCarthy
Nabesna
Seldovia
Seward
Talkeetna
Talkeetna Mts.*
Tyonek
Valdez

Interior Alaska
Ambler River*
Arctic*
Baird Mts.*
Beaver
Bendeleben*
Bethel*
Bettles
Black River
Charley River
Christian
Circle
Coleen*
Dillingham*
Eagle
Fairbanks
Fort Yukon
Healy
Holy Cross
Hughes
Iditarod*
Iliamna
Kantishna River
Kateel River*
Kotzebue*
Lake Clark
Lime Hills
Livengood
McGrath
Medfra
Melozitna
Misheguk Mtn.*
Mt. Hayes*
Mt. McKinley
Noatak*
Nome*
Norton Bay*
Nulato
Ophir*
Ruby
Russian Mission
Shungnak
Sleetmute
Solomon
Survey Pass
Tanacross
Tanana
Taylor Mts.
Unalakleet
Wiseman

Southeast Alaska
Bradfield Canal
Craig
Dixon Entrance
Juneau
Ketchikan
Mt. Fairweather
Petersburg
Port Alexander
Prince Rupert*
Sitka
Skagway
Sumdum
Taku River
Yakutat

Tree damage codes used in 1989-2000 aerial surveys and GIS map products.

* The codes used for 2000 aerial surveys and GIS maps are marked with an asterisk.

ALB	Aspen leaf blight
ALD	Alder defoliation
ALM*	Aspen Leaf Miner
ALR*	Alder leafroller
ASD*	Aspen defoliation
ASF	Alder sawfly
BAP	Birch aphid
BHB	Black-headed budworm
BHS	BHB/HSF
BID*	Birch defoliation
BLM*	Birch Leaf Miner
BLR*	Birch leaf roller
BSB	BHB/SPB
CDL*	Cedar decline
CLB*	Cottonwood leaf beetle
CLM	Cottonwood leaf miner
COD	Conifer defoliation
CTB	Conifer top breakage
CWD*	Cottonwood defoliation
CWW	CWD and WID
FIR*	Fire damage*
FLO*	Flooding/high-water damage
HCK	Hemlock canker
HLO	Hemlock looper
HSF*	Hemlock sawfly
HTB	Hardwood top breakage
HWD	Hardwood defoliation
IPB	*IPS* and SPB
IPS*	*Ips* engraver beetle
LAB	Larch beetle
LAS*	Larch sawfly
LAT*	Large aspen tortrix
OUT*	Out (island of no damage)
POD*	Porcupine damage
SBM	Spruce/Larch budmoth
SBR	Spruce broom rust
SBW*	Spruce budworm
SLD*	Landslide/Avalanche
SMB	Spear-marked black moth
SNA*	Spruce needle aphid
SNR*	Spruce needle rust
SPA	Spruce aphid
SPB*	Spruce beetle
SPC	SPB and CLB
WID	Willow defoliation
WIR	Willow Rust
WLM*	Willow Leafblotch Miner
WNT	Winter damage
WTH*	Windthrow/Blowdown

Note: For all insect activity, the 4th character in the digital data (L, M, or H) denotes intensity. For quantitative descriptors of the intensity levels refer the metadata accompanying the digital data. Digital data can be found at the following URL: http://agdc.usgs.gov/data/projects/fhm/

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